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IDENTIFIERS	Electrical Wiring; Electric Meters; *Power Line Technicians

ABSTRACT

This module is the fifth in a series that is designed to help students achieve greater professional and personal success as power line technicians. Each module represents one or more complete units of instruction with components organized into one instructor and one student "package": the instructor's manual and the student workbook. The instructor's manual begins with a profile of training mastery that lists the competencies covered in the curriculum and provides space for recording information about the student's mastery of each objective. Other introductory matter includes information on use of the manual, recommendations for measuring student performance gains, and required criteria for a competency-based education program. The instructor's manual also contains one set per unit of these components: suggested activities, answers to assignment sheets, answers to test, transparency masters, and test. The student workbook contains one set per unit of most or all of these components: objective sheet, information sheets, assignment sheets, and job sheets. The four units in this module are as follows: (1) meters and meter application, (2) system knowledge, (3) transformer connections and banking, and (4) phasing. Most units are designed for use in more than one lesson or class period. (YLB)

ED 403 414

Power Line Technician
Second Edition

Module E

Instructor's Manual
Student Workbook

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Power Line Technician

Second Edition

Module E

- Meters and Meter Application
- System Knowledge
- Transformer Connections and Banking
- Phasing

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CIMC

Instructor's Manual

97-012244

Oklahoma Department of Vocational and Technical Education
1500 West Seventh Avenue
Stillwater, Ok 74074-4364
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• 111019

POWER LINE TECHNICIAN
PROFILE OF TRAINING MASTERY

Instructor _____ Date _____

Program _____

Grade _____ School _____

Name _____ Soc. Sec. No. _____

Address _____ Phone _____

In Case of Emergency, Contact _____

Address _____ Phone _____

Allergies/Disabilities that might require special accommodation for training (please specify) _____

The above information can be used for school records and/or to ensure safety of students. This confidential information is not to be released to employers or the general public.

Date of Enrollment ___-___-___ Total Class Hours _____ Total Hours Absent _____

Date of Withdrawal ___-___-___ Total On-the-Job Training Hours _____ Total Hours Tardy _____

Date of Completion ___-___-___ Total Lab Hours _____

ON-THE-JOB TRAINING/WORK EXPERIENCE

Duration of Employment	Job Title	Supervisor's Name
Address of Employer		Phone
Duration of Employment	Job Title	Supervisor's Name
Address of Employer		Phone

Use of This Document

This document can be used to record information about the student and skills mastered. This information is useful in documenting student progress during training and in providing information about the student's qualifications to potential employers and/or for entry into advanced training programs. Instructors using these materials are authorized to reproduce this document as required for use in their training programs.

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SPECIFIC JOB COMPETENCIES

Instructor: As each competency is mastered, place your initials and the date in the blank on the left. This will verify that the student can perform the skill with a minimum of supervision.

MODULE A

Date/Initial

Unit 1 – Orientation to REC

1. Match terms associated with REC orientation to the correct definitions.
2. State the reason for establishing the Rural Electrification Administration.
3. Discuss the importance of rural electric cooperatives.
4. Describe the benefits of rural electric cooperatives to rural America.
5. Select from a list the finance agencies which loan money to rural electric cooperatives.
6. List types of electric utilities.
7. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 2 – Introduction to Power Line Technician's Training

1. List responsibilities of a line technician to the community.
2. Select from a list the responsibilities of a line technician to the employer.
3. Select from a list information that is shown on an organizational chart.
4. List departmental functions of a line department.
5. Select from a list topics taught in this course.
6. List benefits to students who complete the line technician's training course.
7. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 3 – Job Advancement

1. Match terms associated with job advancement to the correct definitions.
2. List characteristics employers consider when making promotions.
3. Distinguish between good and poor work attitudes.
4. List steps that will help in job advancement.
5. Select from a list benefits of additional education and training.
6. Discuss activities that will better prepare a person for advancement.
7. Discuss reasons people do not succeed on the job.
8. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 4 – General Safety

1. State the safety responsibilities of an REC employee.
2. List the steps of discipline for safety rule violations.
3. Select from a list items which are subject to safety rules.
4. State reasons for the importance of a safety policy.
5. Discuss OSHA regulations for first aid.
6. List the basic steps in first aid.
7. List steps of basic life support.
8. List first aid supplies.
9. List the practices for care of first aid supplies.
10. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

MODULE B

Date/Initial

Unit 1 – Personal and Job Safety

1. Match terms associated with personal and job safety to the correct definitions.
2. Describe the procedures to follow for various types of rescue situations.
3. List components necessary for fire.
4. Match classes of fires to the correct description of each.
5. Match types of fire extinguisher to the class or classes of fire each is best suited to extinguish.
6. List general safety precautions to observe during rescue.
7. Discuss in a short paragraph driving skills needed by a line technician.
8. List some poor attitudes that may cause accidents.
9. Select from a list requirements of a skilled driver.
10. List steps of defensive driving.
11. Identify shapes of traffic signs.
12. Select from a list some general safety precautions to observe when operating equipment.
13. State OSHA/DOT regulations for inspection of equipment.
14. Select from a list the items which should be inspected daily on mechanical equipment.
15. List methods for maintaining a clean and orderly work area.
16. Explain how to lift heavy objects.
17. Describe in a short paragraph the importance of safety communications.
18. Select from a list those items of importance that should be reported to the supervisor.
19. Select from a list items related to safety that a line technician should know concerning location and voltage.
20. State factors which determine the maximum weight which can be lifted by equipment.
21. Determine maximum weight that can be lifted by equipment at various angles.
22. Complete a safety pledge form.
23. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 2 – Communications

1. List types of communications necessary for an REC employee.
2. Select from a list those items of communication that are important between fellow workers.
3. List items of communication that are important between the worker and the supervisor.
4. Select from a list those items of communication that are important between the worker and the general public.
5. Identify hoist signals.
6. Identify winch line signals.
7. Identify hand signals used in boom operations.
8. Identify hand signals used when maneuvering vehicles.
9. Identify line work signals.
10. Select from a list the proper radio procedures.
11. State emergency radio procedure.
12. Select from a list the prohibited uses of the radio.
13. Match radio code signal numbers to the correct meanings.
14. List factors that are important when using cellular mobile telephones.
15. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Student ratings on specific competencies evaluated during the course are available upon student's written request and/or by calling the instructor. Parent's or guardian's signature is necessary if student is under 18 years of age.

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Date/Initial

Unit 3 – Basic Electrical Theory

1. Match terms associated with basic electrical theory to the correct definitions.
2. List uses of electricity.
3. Discuss the electron theory.
4. Distinguish between alternating and direct current.
5. Match types of magnets to the correct descriptions.
6. State the law of magnetic poles.
7. Describe magnetic force as it relates to production of electricity.
8. Select from a list characteristics of electromagnetic force.
9. Explain the generation of electricity using magnets.
10. Describe electromagnetic induction.
11. Identify types of circuits.
12. Identify conditions of circuits.
13. Name sources of alternating and direct current.
14. Identify divisions of an electrical system.
15. State the relationship among amperage, resistance, and voltage.
16. Solve problems using Ohm's law.
17. Calculate for an unknown voltage.
18. Calculate for an unknown amperage.
19. Calculate for an unknown resistance.
20. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 4 – Rope and Rigging

1. Match terms associated with rope and rigging to the correct definitions.
2. Identify parts of a stationary block.
3. List kinds of rope used in line work.
4. Determine the tensile strength of various kinds and sizes of rope.
5. Determine the mechanical advantage of using block and tackle.
6. List uses of various types of rope gear.
7. Apply the formula necessary for the safe working load of various kinds and sizes of ropes when given the tensile strength and safety factory.
8. Identify various knots and hitches.
9. Match various knots and hitches with the correct uses.
10. Identify elements of knots, bends, and hitches.
11. List conditions that damage rope.
12. Calculate the mechanical advantage of using block and tackle.
13. Calculate working load of various ropes.
14. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 5 – Overhead Construction

1. Match terms associated with overhead construction to the correct definitions.
2. Match materials commonly used in overhead construction to their specific uses.
3. Identify hand tools commonly used in overhead construction.
4. Match hand tools to their specific uses.
5. Identify overhead construction tools.
6. Match overhead construction tools to their specific uses.
7. List elements of overhead construction.
8. List equipment used in overhead construction.
9. Match equipment commonly used in overhead construction to their specific uses.
10. Select from a chart the correct depth to set poles of varying lengths.
11. List methods used to properly sag conductors.
12. Identify various types of connectors used in overhead construction.
13. Match types of construction to the correct descriptions.
14. List steps to properly install a pole key.
15. State correct procedure for installing a ground rod.
16. Arrange in order the steps to follow when framing a pole.
17. Identify various structures used in transmission line construction.
18. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 6 – Underground Distribution Construction

1. Match terms associated with underground construction to the correct definitions.
2. Identify equipment used in underground construction.
3. Match various types of equipment to the specific uses.
4. List general requirements for underground construction.
5. Arrange in order the correct procedure for installing cable.
6. List precautions to observe when handling underground cable.
7. Select from a list methods of marking cable for identification.
8. List methods used to locate and identify a utility ditch.
9. Identify equipment used to terminate primary cable on a pole.
10. State the requirement for grounding underground equipment.
11. List hazards which may be encountered in underground construction.
12. List precautions to observe when splicing or terminating cable.
13. Select from a list the tools used in underground construction.
14. Make a proper splice in secondary cable.
15. Make a proper splice in primary cable.
16. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 7 – Personal Climbing Tools and Equipment

1. Match terms associated to personal climbing tools and equipment to the correct definitions.
2. Identify personal climbing tools and equipment.
3. Match tools and equipment to the specific use.
4. List conditions to watch for when inspecting personal climbing tools and equipment.
5. Name types of maintenance for personal climbing tools and equipment.
6. List safety precautions to observe when climbing poles.
7. Select from a list the general procedure for climbing poles.
8. Name rules for safe and proper storage of personal tools and equipment.
9. Climb poles.
10. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 8 – Right-Of-Way

1. Match terms associated with right-of-way clearing and control to the correct definitions.
2. List methods to maintain good public relations.
3. Identify tools used for right-of-way clearing and control.
4. State the purposes of right-of-way control.
5. Select from a list the safe working procedures for right-of-way clearing and control.
6. Select proper methods of tree trimming.
7. List steps to remove limb hanging over an energized conductor.
8. List steps to fell a tree.
9. State the specifications for clearing right-of-way for distribution line.
10. List types of clearing and chemical control for right-of-way.
11. Identify various trees that grow rapidly.
12. Identify poisonous vegetation.
13. Draw cuts needed to remove heavy limbs.
14. Draw procedure for removing limb hanging over energized conductor.
15. Draw procedure for felling a tree.
16. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

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Date/Initial

Unit 9 – Distribution Transformers

1. Match terms associated with transformers to the correct definitions.
2. State the functions of a transformer.
3. Identify parts of a completely protected transformer.
4. Distinguish between additive and subtractive polarity as they relate to transformers.
5. List kinds of transformers.
6. Match types of transformers to the correct descriptions.
7. Classify types of transformers as oil-cooled or air-cooled.
8. Discuss technical considerations in protective grounding and jumpering.
9. List information found on a transformer nameplate.
10. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

MODULE C

Date/Initial

Unit 1 – Poles

1. Match terms associated with poles to the correct definitions.
2. List five types of preservatives used on poles.
3. Match the type of preservatives used on poles with their code letters.
4. Select from a table the classes of poles of varying lengths and circumferences.
5. Select from a list precautions to observe when handling poles.
6. Calculate the weights of various classes and lengths of commonly used poles using a table.
7. List methods used to set poles.
8. State the correct procedure for checking a pole before climbing.
9. Arrange in proper order the steps for pole inspection.
10. List methods used to support unsafe poles for climbing.
11. State the correct method for storing poles.
12. Select from a table the classes of poles of varying lengths and circumferences.
13. Calculate the weights of various classes and lengths of commonly used poles using a table.
14. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 2 – Conductors

1. Match terms associated with line conductors to the correct definitions.
2. List methods used to protect line conductor at supports.
3. Arrange in order the steps to follow when joining ACSR conductors.
4. Arrange in order the steps to follow when joining CWC conductors.
5. List classes of conductors.
6. List methods of reeling our conductor.
7. Identify various types of conductor ties.
8. Match types of conductors to their specific use.
9. State conductor clearance from ground, roofs and building walls for conductors carrying 750 volts or less.
10. State conductor clearance from ground for conductors carrying over 750 volts to 22,000 volts.
11. Match current-carrying capacities of various ACSR conductors to the correct conductor size.
12. Match current-carrying capacities of various copperweld copper conductors to the correct conductor size.
13. Install a preformed line tie on ACSR conductor on a de-energized circuit.
14. Install a top groove conductor tie on a de-energized copper conductor.
15. Install a preformed armor rod on ACSR conductor.
16. Join ACSR conductor.
17. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 3 – Grounding and Connecting

1. Match terms associated with grounds and connectors to the correct definitions.
2. State the purposes of grounding.
3. List methods of grounding.
4. Select from a list those elements necessary for good grounding.
5. Select from a list equipment which must be grounded.
6. State the correct procedure for installing temporary protective grounds.
7. Arrange in order the steps to follow when disconnecting and grounding at sectionalizer or recloser station.
8. Arrange in order the steps to follow when disconnecting and grounding at multiphase vertical corner.
9. State the procedure for installing temporary protective grounds at air-break switch on a transmission line.
10. List elements of a good connection.
11. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 4 – Generators and Batteries

1. Match terms associated with generators and batteries to the correct definitions.
2. List kinds of generating plants.
3. Match kinds of generators to the voltages produced by each.
4. Match kinds of generators to the specific uses.
5. Calculate the frequency (Hertz) of various generators.
6. List precautions to observe with the use of portable generators.
7. List types and kinds of voltage-producing cells.
8. Identify various circuits of connected batteries.
9. Select from a list precautions to observe when connecting batteries.
10. Arrange in order the steps to follow to connect lead-acid batteries when starting equipment.
11. Connect batteries in series and parallel.
12. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 5 – Work Procedures (Nonenergized)

1. Match terms associated with work procedures to the correct definitions.
2. Select from a list information found on a staking sheet.
3. Arrange in proper order the procedure for line construction.
4. List steps to follow when installing service wire.
5. State the procedure for connecting service wire.
6. Match the materials needed to construct primary and neutral assemblies using ACSR conductor 7.2kV construction.
7. List materials needed to install various pole ground assemblies.
8. List materials needed for various primary assemblies.
9. List materials needed to complete a work order.
10. Identify section numbers within a township.
11. Locate rural property in Oklahoma using legal descriptions.
12. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

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MODULE D

Date/Initial

Unit 1 – Insulation

1. Match terms commonly associated with insulators and insulation to their correct definitions.
2. List steps to follow when installing a pin type insulator.
3. Select from a list methods of insulating distribution voltages.
4. Select from a list methods of insulating various transmission voltages on wooden structures.
5. Match insulative materials to their specific uses.
6. Select from a list precautions to observe with insulators and insulation.
7. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 2 – Substations

1. Match terms commonly used with substations to the correct definitions.
2. State functions of a substation.
3. Identify components of a substation.
4. Match components of a substation to their specific use.
5. Arrange in order the steps for taking a substation out of service.
6. Select from a list precautions to observe with a substation.
7. Arrange in order the correct procedure for changing a substation oil circuit recloser.
8. State the correct procedure for bypassing a substation current transformer.
9. List indications in a substation that could cause an outage.
10. Match indications to problems which may occur in substations.
11. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 3 – Ground and Jumpers (Line Equipment)

1. Match terms commonly used with grounds and jumpers to the correct definitions.
2. Match types of jumpers to their specific use.
3. State requirements for various jumpers.
4. Select from a list the line equipment that is connected by jumpers.
5. Match types of jumpers to the correct installation methods.
6. State the requirements for safe grounding of line equipment.
7. Distinguish between proper and improper grounding methods.
8. Calculate current flow of faulted equipment which is improperly grounded.
9. Calculate voltage on improperly grounded faulted equipment.
10. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 4 – Voltage and Current Measuring

1. Match terms commonly used with voltage and current measurements to the correct definitions.
2. State the purposes of voltage and current measurements.
3. Identify equipment used for voltage and current measurements.
4. State the correct procedure for determining voltage drop of a service.
5. State the correct procedure for determining current demand on a primary circuit in a specific area.
6. State procedures for determining current demand on a transformer.
7. List steps to obtain primary line voltage drop.
8. Select from a list reasons for current measurements.
9. Match full load secondary current at 240 volts single phase to the kVA ratings of a transformer.
10. Select from a list precautions to observe when making voltage and current measurements.
11. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

MODULE E

Date/Initial

Unit 1 – Meters and Meter Application

1. Match terms commonly associated with metering to the correct definitions.
2. List general types of meters.
3. List types of meters by base construction.
4. List classes of meters and the current-carrying capacity of each.
5. Match meters to types of service.
6. Match meter to voltage ratings to types of service.
7. Match abbreviations and symbols used with metering circuit diagrams to the correct meanings.
8. List uses of current transformer metering.
9. List uses of self-contained meter connections.
10. Identify various self-contained meter connections.
11. Identify various transformer-rated meter connections.
12. Identify various transformer-rated meter connections for 600 volts or above.
13. State the procedure for selecting the correct meter.
14. List methods for determining voltage for wye and delta connected meters.
15. Match types of services to specific uses.
16. List types of meters which have multipliers.
17. Arrange in order the correct procedure for determining meter mutipliers.
18. List precautions to observe with metering.
19. Calculate the multiplier for a transformer-rated meter connected to a secondary line.
20. Calculate the multiplier for a transformer-rated meter connected to a primary line.
21. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 2 – System Knowledge

1. Match terms used with system knowledge to the correct definitions.
2. Define symbols used with overhead lines and equipment identification on system maps.
3. Define symbols used with underground lines and equipment identification on system maps.
4. Identify symbols used to locate cultural features on system maps.
5. List functions of automated equipment.
6. List precautions to observe with automated equipment.
7. Select from a list conditions associated with system terrain.
8. Identify symbols on a system map.
9. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

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Date/Initial

Unit 3 – Transformer Connections and Banking

1. Match terms commonly used with transformer connections and banking to the correct definitions.
2. Define characteristics of transformer construction.
3. Match symbols used with transformer voltage rating and connection diagrams to the correct meanings.
4. Discuss transformer polarities.
5. Discuss bushing locations in relationship to polarity on padmount transformers and compare to pole-type in regard to subtractive and additive.
6. Identify secondary coil connections for two- and three-wire service.
7. Identify single-transformer connections for three-wire service.
8. Identify two-transformer banks.
9. Define objectives an electrician must keep in mind when constructing three-phase banks.
10. List in order the step-by-step process for designing three-phase banks.
11. Describe phase relationships between the bushings in three-phase banks.
12. Identify types of primary and secondary connections for three-transformer banks.
13. List precautions to observe when selecting transformers to be banked or paralleled.
14. Identify secondary connections on a four-bushing transformer.
15. State the correct method of connecting wye and delta transformers to a primary line.
16. Arrange in order the steps to find a faulted transformer in a bank.
17. State the precautions to observe with transformer banks.
18. Connect transformer secondary coils in series and parallel.
19. Connect a wye-delta bank for three-phase four-wire 120/240-volt service.
20. Connect a wye-delta bank for three-phase three-wire 240-volt service.
21. Connect a wye-wye bank for three-phase four-wire 120/208-volt service.
22. Connect an open-wye open-delta bank for three-phase four-wire 120/240-volt service.
23. Connect an open-wye open-delta bank for three-phase three-wire 240-volt service.
24. Connect an open-delta open-delta bank for three-phase four-wire 120/240-volt service.
25. Connect two single-bushing transformers in parallel.
26. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 4 – Phasing

1. Match the terms commonly associated with phasing to the correct definitions.
2. List elements of phasing.
3. State methods of determining phase rotation.
4. State the procedure for changing the direction of rotation of a three-phase motor.
5. Arrange in order the steps to follow when phasing circuits with a phasing meter.
6. Arrange in order the steps to follow to identify distribution phases.
7. Label substation distribution phases.
8. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

MODULE F

Date/Initial

Unit 1 – Line Patrol

1. Match types of line patrol to the specific purpose.
2. Select from a list items to observe when patrolling line.
3. Match items to the specific conditions to observe when patrolling a line.
4. List methods of line patrol.
5. Select from a list requirements of a line patroller.
6. List items to observe with line equipment.
7. Complete a line inspection form.
8. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 2 – Electrical Equipment

1. Match terms used with electrical equipment to the correct definitions.
2. Match electrical equipment to the specific uses.
3. Arrange in order the steps to follow when connecting a voltage regulator to a three-phase line.
4. Arrange in order the steps to follow when placing a voltage regulator in service.
5. State the procedure for setting voltage regulator time delays.
6. State the procedure for taking a voltage regulator out of service.
7. List precautions to observe with voltage regulators.
8. List precautions to observe with capacitors.
9. Select from a list the benefits of capacitor application.
10. Name equipment that should be protected by lightning arresters.
11. Explain the method of coordinating reclosers with other reclosers.
12. List precautions to observe when installing sectionalizers.
13. Select from a list factors to consider when coordinating reclosers and fuses.
14. Connect voltage regulators to a three-phase line.
15. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 3 – Work Procedures (Hot Line, Basket, Hot Stick)

1. List methods of hot line maintenance.
2. Select from a list OSHA requirements for aerial devices.
3. Select from a list rules to observe when working with aerial devices.
4. List elements of hot line maintenance.
5. State the procedure for hot line maintenance from an aerial device.
6. Arrange in order the steps to follow when changing a pole top insulator from a basket.
7. Match various hot line tools to their specific uses.
8. Install a wire tong saddle.
9. Change an insulator on an energized conductor using hot line tools on an A1 structure.
10. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial

Unit 4 – Troubleshooting (Secondary)

1. Match terms associated with troubleshooting to the correct definitions.
2. Match indications of malfunctions to the possible causes.
3. Arrange in order the correct procedure for troubleshooting electrical equipment.
4. List precautions to observe when troubleshooting electrical equipment.
5. Select from a list items of information to obtain while troubleshooting.
6. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

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MODULE G

Date/Initial	*Unit 1 – Troubleshooting (Primary Line)*
_____	1. Match troubleshooting problems to possible causes.
_____	2. Arrange in order the troubleshooting procedures to follow for various problems.
_____	3. List precautions to observe when troubleshooting primary lines.
_____	4. Arrange in order the steps for troubleshooting a primary line outage.
_____	5. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial	*Unit 2 – System Knowledge*
_____	1. List problems associated with line switching.
_____	2. Arrange in order the steps to follow when switching line.
_____	3. List factors involved in line switching.
_____	4. Select from a list precautions to observe with line voltage regulators on a switched line.
_____	5. List precautions to observe when opening a line switch.
_____	6. Select from a list areas and locations of importance to the line technician.
_____	7. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

Date/Initial	*Unit 3 – Conversions*
_____	1. List types of conversions.
_____	2. Arrange in order the steps to convert a primary line to a higher voltage.
_____	3. Arrange in order the steps to change a substation feed area to a higher voltage.
_____	4. Explain benefits of converting to a higher voltage.
_____	5. Select from a list precautions to observe with autotransformers.
_____	6. Arrange in order the steps to convert a single-phase line to V-phase.
_____	7. Arrange in order the steps to convert a single-phase line to three-phase.
_____	8. _____

Pretest Score (%) _____

Post Test Score (%) _____

Modified Gains Score (%) _____

BEST COPY AVAILABLE

Power Line Technician: Module E

Instructor's Manual

Upfront

Suggested Activities

Answers to Assignment Sheets

Answers to Test

Transparency Masters

Test

Developed by the
Curriculum and Instructional Materials Center
Oklahoma Department of Vocational and Technical Education

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Curriculum and Instructional Materials Center

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Instructor's Manual

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One set per unit of the following components:

- Suggested Activities
- Answers to Assignment Sheets
- Answers to Test
- Transparency Masters
- Test

Student Workbook

One set per unit of Objective Sheets, Information Sheets, Assignment Sheets, and Job Sheets for each of the units in this module:

MODULE A

1. Orientation to REC
2. Introduction to Power Line Technician's Training
3. Job Advancement
4. General Safety

MODULE B

1. Personal and Job Safety
2. Communications
3. Basic Electrical Theory
4. Rope and Rigging
5. Overhead Construction
6. Underground Distribution Construction
7. Personal Climbing Tools and Equipment
8. Right-of-Way
9. Distribution Transformers

MODULE C

1. Poles
2. Conductors
3. Grounding and Connecting
4. Generators and Batteries

5. Work Procedures (Nonenergized)

MODULE D

1. Insulation
2. Substations
3. Grounds and Jumpers (Line Equipment)
4. Voltage and Current Measuring

MODULE E

1. Meters and Meter Application
2. System Knowledge
3. Transformer Connections and Banking
4. Phasing

MODULE F

1. Line Patrol
2. Electrical Equipment
3. Work Procedures (Hot Line, Basket, Hot Stick)
4. Troubleshooting (Secondary)

MODULE G

1. Troubleshooting (Primary Line)
2. System Knowledge (Phase II)
3. Conversions

FOREWORD

The *Power Line Technician* series is designed to help students achieve greater professional and personal success. As a tool for building a rewarding career, this series will help students develop their professional competence. In addition, the series provides a foundation for career advancement. The *Power Line Technician* series consists of seven modules which address specific skill areas. Each module represents one or more complete units of instruction with components organized into one student and one instructor "package": the *Student Workbook*, and the *Instructor's Manual*. We believe the format and packaging will facilitate both the delivery and mastery of the identified competencies.

We hope that this series will enhance instruction and contribute to rewarding learning experiences for all students.

Roy Peters, Jr.
State Director
Oklahoma Department of
Vocational and Technical Education

Ivan Armstrong
State Supervisor
Trade and Industrial Education

ACKNOWLEDGMENTS

The Curriculum and Instructional Materials Center (CIMC) extends its appreciation to the individuals who played key roles in the development of this publication. Such a comprehensive effort requires contributions from many people. We sincerely appreciate the support necessary to complete this project.

Design: Special thanks are extended to the representatives from industry, teaching, and vocational education who participated as members of the curriculum advisory committees for the *Power Line Technician* series. We also thank the administrators, supervisors, and others who supported their participation. Significant contributions were made during the revision process by participants from ABB Power T&D Company Inc., the Association of Missouri Electric Cooperatives, the Central Rural Electric Cooperative (Stillwater, Oklahoma) and the City of Stillwater.

Development: The modules in this series were edited by Craig Maile and Dr. Lois Sharpton. Individual modules were formatted by Vonda Gile. Brenna Tillman, Publications Supervisor in the CIMC, assisted in adapting the packaging.

Production: The close cooperation and dedication of professionals at the Oklahoma Department of Vocational and Technical Education were instrumental in producing the *Power Line Technician* series. Unit and cover artwork were designed by the Art Department, under the direction of Bob Davis, Art Manager. This series could not have been printed without the expertise and commitment of the Printing Plant Staff, under the direction of Danny Darrow. Delivering the final product was accomplished through the excellence of the CIMC Customer Service staff and the staff of the CIMC Warehouse, under the direction of Darrell Stiles.

Support: A number of people at the CIMC helped to make this series possible. Terri Tomson efficiently handled the development contracts, committee meetings, and correspondence relating to this series. This project also received generous support from John Friedemann, CIMC Team Leader, and Dr. Lynna Ausburn, Development Coordinator.

Project Management: Dr. Marilyn Troupe and Craig Maile

USE OF THIS PUBLICATION

Each unit of instruction is based on the performance needed for successful employment in an occupational area. A complete unit will contain most or all of the following components: Objective Sheet, Suggested Activities, Information Sheet, Assignment Sheet, Job Sheet, Test, Answers to Assignment Sheets, Answers to Test, and Transparency Masters. These components are organized within two packages, as follows:

Instructor's Manual

- Upfront pages
- One set per unit of:
  - Suggested Activities
  - Answers to Assignment Sheets
  - Answers to Test
  - Transparency Masters
  - Test

Student Workbook

- Objective Sheets
- Information Sheets
- Assignment Sheets
- Job Sheets

Instructor's materials include the *Instructor's Manual* and the *Student Workbook*.

Unit components are tied to measurable and observable learning outcomes. Instructors are encouraged to supplement unit components with other resources to make units as responsive to local conditions and student needs as possible.

Most units of instruction are designed for use in more than one lesson or class period. Instructors should determine the following for each unit:

- amount of material that can be covered in each class period;
- skills that must be demonstrated;
- supplies and equipment needed;
- amount of class time needed for demonstrations;
- amount of class time needed for student practice;
- supplementary materials to be ordered; and
- resource persons who must be contacted.

Objective Sheet (Student Workbook)

The Objective Sheet summarizes each unit for the student and the instructor. The Objective Sheet includes the following sections:

> **Unit Objective** – The Unit Objective states the overall goal of the unit. It identifies what the student will be able to do after successfully completing the unit, as well as the standards used to measure student performance.
>
> **Specific Objectives** – The Specific Objectives outline the teaching sequence of the competencies required to reach the Unit Objective.

The Specific Objectives on the Objective Sheet should be emphasized to all students at the start of each unit and throughout the teaching/learning process. This will help answer student questions about performance requirements for each unit. Specific Objectives can also assist instructors in determining teaching strategies and instructional methods. Instructors should prepare for each unit by deciding how each objective could best be taught.

Instructors should modify, delete, or add objectives to meet the needs of students and the community. When objectives are added, the instructor should remember to provide the needed information, Assignment and/or Job Sheets, and criterion-referenced test items to cover the new objectives.

Information Sheet (Student Workbook)

The Information Sheet provides the "must know" content essential for meeting the cognitive objectives in the unit. The Information Sheet may include clarifying NOTES and EXAMPLES, as needed. Students should read the Information Sheet for each unit before it is discussed in class.

Assignment Sheets (Student Workbook)

The Assignment Sheets address the learning levels at or above the application level of Bloom's taxonomy. They allow students to perform non-psychomotor activities related to occupational tasks. Assignment Sheets also provide students with an opportunity to use higher-order thinking skills, such as problem-solving, synthesizing, analyzing, and evaluating. In addition, they may provide opportunities for cooperative learning and more detailed oral/written communication activities.

Job Sheets (Student Workbook)

Job Sheets give students step-by-step procedures for performing manipulative or psychomotor occupational tasks or jobs. The Job Sheet also facilitates the instructor's evaluation of each student's performance. Both the process and the end-product are evaluated. Diagrams, illustrations, and photographs are included, as needed, to assist students in completing the job.

The instructor should demonstrate the procedure outlined in each Job Sheet. Instructors may also have to localize specific procedures.

Suggested Activities (Instructor's Manual)

Instructors should study the Suggested Activities before introducing the unit, allowing enough time to obtain supplemental materials, prepare audiovisual materials, and contact outside resource persons. Specific tasks of the instructor will vary with each unit.

Answers to Assignment Sheets and Answers to Test (Instructor's Manual)

These components list the answers to all of the Assignment Sheets and the Test questions.

Transparency Masters (Instructor's Manual)

Transparency Masters are provided so that instructors can make transparencies to accompany specific units. Transparencies allow students to *see* as well as hear the information being presented, thus reinforcing the learning process. They also direct attention to the topic under discussion. Transparencies should be left on the screen only when the related topics are under discussion.

Test (Instructor's Manual)

The Test provides criterion-referenced evaluation of the Specific Objectives from the Information Sheet (Assignment Sheet and Job Sheet objectives are not evaluated by the Test). If instructors have added, deleted, or modified any objectives, appropriate changes should be made to the Test as well.

The Test serves as both a pretest and a posttest. In order to measure and document student competency gains as required by the latest Carl Perkins regulations, and as outlined in the Oklahoma-developed system of standards and measures, it is *essential* that the same test be used as a pretest and as a posttest. If instructors choose to use tests other than the unit Test, they should make sure that the same instrument is used for each activity – pre- and posttest.

A detailed explanation of the Oklahoma plan for standards and measures and the Carl Perkins requirements is included in the CIMC publication *Measuring Learning & Competency Gains: The Pretest/Posttest Approach.* This booklet – and accompanying software to assist in calculating and recording student gains – are available to Oklahoma instructors through their school's vocational-testing liaison.

Profile of Training Mastery

The Profile of Training Mastery documents student performance. Each profile lists the competencies covered in the curriculum, and provides space for recording information about the student and the student's mastery of each objective. Space is also provided for recording pre- and posttest scores, modified gains, and instructor comments. A blank Profile of Training Mastery is available for this series. It may be reproduced for each student.

Page Numbering

Each Module is identified with a letter (A - G). Each unit and page has a number, shown in Arabic numerals. For example, the page number for Module A, Unit 2, page 3 of the *Student Workbook* would appear as follows:

PLT A - 2 - 3

Methods of Disseminating Material

For best results, provide each student with a copy of the Student Workbook. Students should be allowed to keep their Workbooks at the end of the course or training program.

Teaching Methods

Keeping students motivated is a challenge. Supplement each unit with current information, personal experiences, and other information. In a group setting, prepare for each unit by determining the best way to teach each objective, and allow for student input. For individualized instruction, provide opportunities for the student to become involved in planning and being responsible for his or her own education.

MEASURING STUDENT PERFORMANCE GAINS

Each CIMC unit contains only a single unit Test. This test should be used as **both** pretest and posttest by giving it once before students start a unit and again when they have completed the unit.

The reason for using a single instrument as both pretest and posttest is so that direct comparison of each student's competencies before and after instruction can be made accurately. This comparison enables precise calculation, documentation, and evaluation of student **performance gains**.

Accurate performance gains analysis is an important requirement of the new Carl Perkins legislation for vocational education. Teachers can make an important contribution to the performance accountability mandated by the new federal legislation by carrying out accurate performance gains analysis for their students, and making this data available to students, parents, and administrators.

This analysis is easy to do and requires only simple calculations and record keeping. Detailed information regarding performance gains analysis is contained in the CIMC publication, *Measuring Learning & Competency Gains: The Pretest/Posttest Approach*. In addition, the CIMC has developed a computer program, CARL, which will perform all necessary calculations and will print out a record form of all information required for gain score analysis. Copies of CARL and the publication are available through your local testing liaison (in Oklahoma), or from the CIMC at 1-800-654-4502.

REQUIRED CRITERIA FOR A COMPETENCY-BASED EDUCATION PROGRAM

Criterion	Discussion	CIMC component meeting criterion
1. Instruction is based on clearly-stated learning objectives that are: a) observable and measurable, and b) communicated in writing to students before instruction begins.	Learning objectives drive CBE. Objectives are the "competencies" that learners must achieve. Each objective must clearly state what *learners* must *do* to demonstrate acquired skill or knowledge. Verbs in learning objectives are active and precise, stating the exact performance expected of learners. The objectives should also specify the standard or level of performance required. Objectives can be at any level of Bloom's Taxonomy and can include the cognitive, psychomotor, and affective domains. Higher-order cognitive skills should be included.	Objective Sheet
2. Instruction is aligned with the stated learning objectives.	In CBE, the objectives specify what is taught. "Content" should relate to one or more objectives. The curriculum should cover all objectives with relevant information.	Information Sheet
3. There is a student evaluation system that is: a) criterion-referenced, and b) aligned to the learning objectives and the curriculum.	In CBE, the aim is to bring the performance of *all* learners up to a pre-defined standards and competencies. Learners work on each competency until they achieve "mastery"; the evaluation system should test and record this mastery. Learners can restudy and retest as often as needed. Specific remediation activities should also be available to learners when needed. The evaluation system focuses on what each student has achieved, not on what the instructor has "taught." The "constant" in CBE is student performance; the "variables" are time and resources. (This differs from traditional systems where learners get one chance at mastery; some succeed and some fail. In such systems, time and resources are constant and student achievement is variable.) If an evaluation is criterion-referenced, successful learner performance is defined by (or *referenced* to) mastery of pre-set objectives and standards (or *criteria*): there must be a careful match (or *alignment*) between what the student should master (objectives), what is taught (curriculum), and what is tested. Objectives, curriculum, and evaluation system must all match.	Test and Job Sheet

Criterion	Discussion	CIMC component meeting criterion
4. There is an observable management system of cognitive skill practice that provides for, promotes, and documents mastery learning.	For both cognitive and psychomotor skills, a CBE program must have a system of maintaining records of which skills and activities each learner has completed, which ones are in progress, and which ones have not yet been completed. Completion means "mastery"; no skill is completed until the learner has achieved the mastery level. The record system should promote feedback on student skill attainment to *both* instructor and learners, provide for remediation as needed, and encourage reevaluation of learner performance until mastery is achieved. Appropriate remediation strategies often should consider learning styles and other individual differences among learners. Learners should work on skills and activities until they achieve mastery. They should not be "passed on" without mastery. While learners may move ahead and work on other skills (i.e those for which all prerequisite skills have been mastered or those without prerequisites), work should also continue on the skills still requiring mastery. Students should not attempt higher-order skills until all prerequisite skills are mastered.	Assignment Sheet
5. There is an observable management system of psychomotor skill practice that provides for, promotes, and documents mastery learning.		Job Sheet
6. Skill mastery records are maintained for each learner, and learners have access to and make use of these records to monitor their skill acquisition.	Records should clearly indicate the skills each learner has mastered. One such record should profile or list the competencies that have been mastered and those to be mastered. Other performance indicators can be added and kept in a portfolio for each learner. Learners should have ready access to their portfolios to monitor their own progress in skill mastery and competency attainment.	Profile of Training Mastery

CORRECTIONS AND SUGGESTIONS

The Curriculum and Instructional Materials Center (CIMC) wants to provide vocational instructors and students with accurate and effective materials. Although the CIMC strives to maintain the highest standards of development and production, oversights sometimes do occur. If you find any errors in this or other CIMC publications, or have suggestions for improving their usefulness in vocational programs, please notify the CIMC staff. To do this, please identify the page(s) affected and write any comments to clarify the error or suggestion. Use the spaces below. Then, simply fold (bottom of page *upward*, top *downward*), secure, and mail.

This information will be used to correct the publication before the materials are reprinted. To ensure that the material is updated on a timely basis, notify the CIMC of necessary corrections as soon as possible after discovering the error.

[2] Fold downward

Page: Comment:

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METERS AND METER APPLICATION
UNIT 1

SUGGESTED ACTIVITIES

1. Suggested activities for instructor:

   - Provide student with objective sheet.
   - Provide student with information and assignment sheets.
   - Make transparencies.
   - Discuss unit and specific objectives.
   - Discuss information and assignment sheets.
   - Show films and other supplemental material on metering.
   - Give test.

2. Unit references:

   - *Power Line Technician.* Stillwater, OK: Oklahoma Department of Vocational and Technical Education, Curriculum and Instructional Materials Center, 1978.

METERS AND METER APPLICATION
UNIT 1

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet 1

R_r = 55 5/9 = 500/9

K_h = 1.8 = 18/10

G_r = 100:1 = 100/1

CT ratio = 400:5 = 400/5

500/9 x 18/10 x 100/1 x 400/5 = 800,000

$$\frac{800,000}{10,000} = 80$$

Meter multiplier is 80

Assignment Sheet 2

R_r = 166 2/3 = 500/3

K_h = 1.8 = 18/10

G_r = 50:1 = 50/1

CT_r = 10:5 = 10/5

PT_r = 60:1 = 60/1

500/3 x 18/10 x 50/1 x 10/5 x 60/1 = 1,800,000

$$\frac{1,800,000}{10,000} = 180$$

Meter multiplier is 180

METERS AND METER APPLICATION
UNIT 1

ANSWERS TO TEST

1. a. 6
   b. 10
   c. 3
   d. 11
   e. 9
   f. 7
   g. 8
   h. 4
   i. 1
   j. 5
   k. 2
   l. 13
   m. 12
   n. 20
   o. 17
   p. 16
   q. 18
   r. 19
   s. 14
   t. 15

2. a. Digital
   b. Self-contained
   c. Transformer-rated

3. a. Socket base ("S" base)
   b. Bottom connected ("A" base)

4. a. Class 10, maximum current of 10 amperes
   b. Class 20, maximum current of 20 amperes
   c. Class 100, maximum current of 100 amperes
   d. Class 200, maximum current of 200 amperes

5. a. Single-phase, two-wire
   b. three-wire
   c. Three-phase three-wire delta
   d. Three-phase four-wire delta
   e. wye, four-wire wye

ANSWERS TO TEST

6. a. 1
   b. 2
   c. 2
   d. 2
   e. 1

7. a. 14.
   b. 16
   c. 4
   d. 5
   e. 17
   f. 3
   g. 12
   h. 8
   i. 2
   j. 10
   k. 13
   l. 11
   m. 9
   n. 6
   o. 15
   p. 18
   q. 7
   r. 1

8. a. Loads greater than 200 amperes
   b. Voltages of 480 or higher
   c. Locations where it would be impractical to install a large metering conductor

9. a. Loads of 200 amperes or less
   b. Voltages of 480 volts or less

10. a. Three-wire single-phase 120/240-volt service
    b. Four-wire three-phase 120/240-volt delta service
    c. Two-wire single-phase 120-volt service
    d. Three-wire three-phase 240-volt corner ground delta service
    e. Four-wire three-phase 120/208-volt wye service

ANSWERS TO TEST

11. a. Three-wire single-phase 240/480-volt service
    b. Four-wire three-phase 120/240-volt delta service
    c. Three-wire three-phase 240-volt delta service
    d. Three-wire single-phase 120/240-volt service
    e. Four-wire three-phase 120/208-volt wye service
12. a. Three-wire three-phase delta primary metering
    b. Four-wire three-phase wye primary metering
13. a. Determine class of meter needed
    b. Determine voltage to be metered
    c. Determine phase of meter
    d. Determine service connection
    e. Determine wires of meter
14. a. Meter voltage will be line-to-ground voltage of service
    b. Meter voltage will be line-to-line voltage of service
15. a. 6 d. 4
    b. 5 e. 2
    c. 3 f. 1
16. a. All transformer-rated meters
    b. Some self-contained meters used on heavy loads
17. a. 3
    b. 4
    c. 1
    d. 2

ANSWERS TO TEST

18. a. Wear eye protection

    b. Wear your rubber gloves

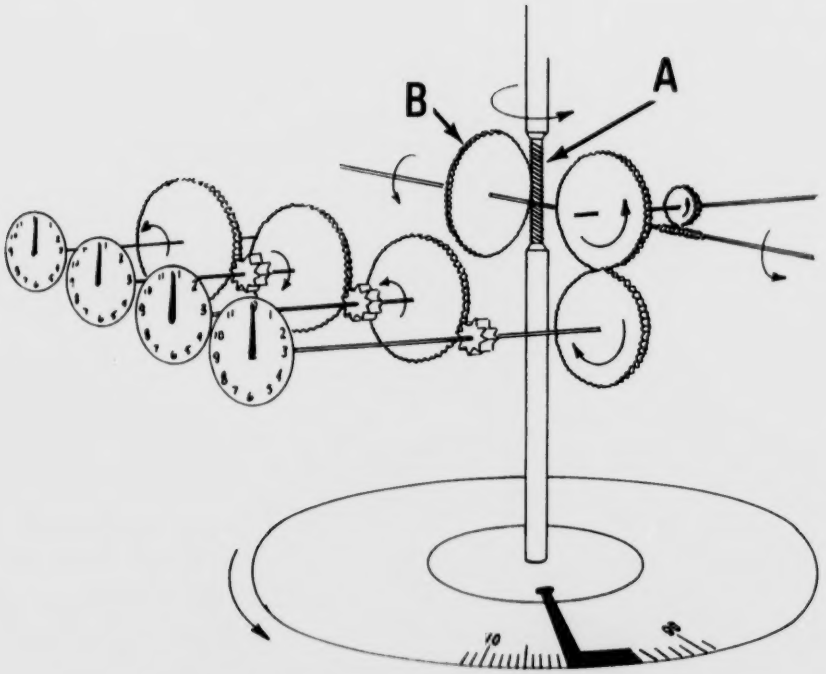
    c. Do not remove a meter which is under load

    d. Short circuit the secondary side of current transformers before removing the meter

19. Evaluated on Assignment Sheet 1.

20. Evaluated on Assignment Sheet 2.

Meter Register

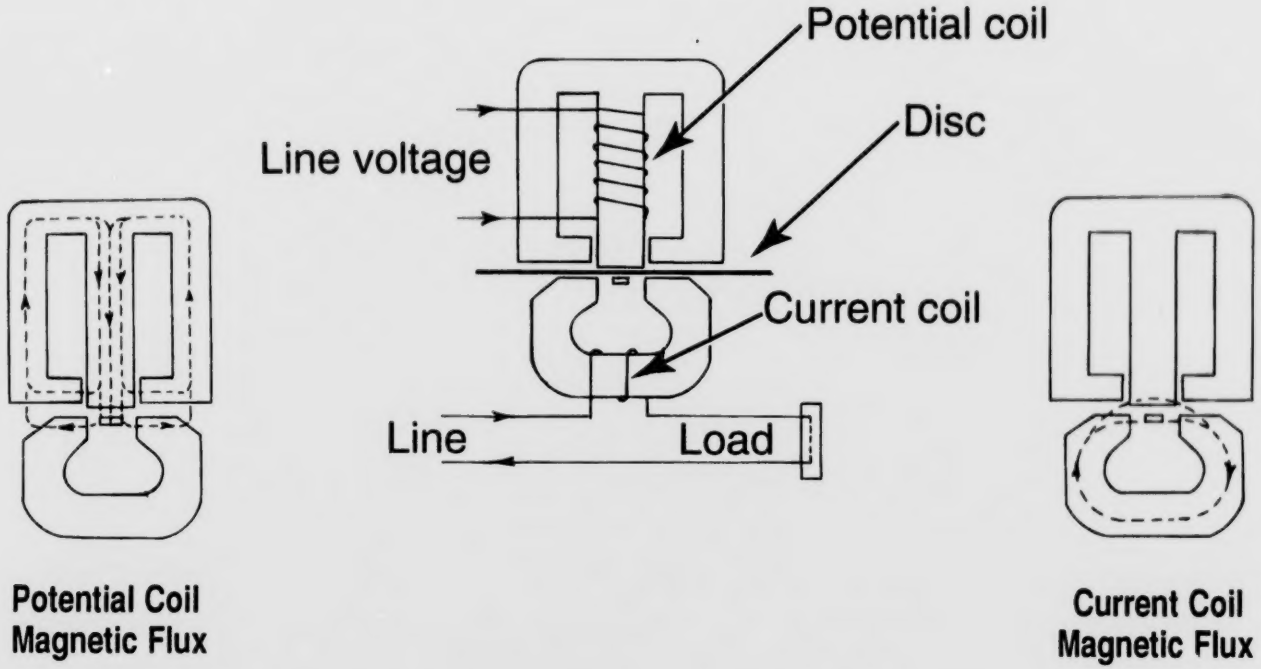


First Reduction

Revolutions of worm drive "A" to one revolution of gear "B" (Usually 100 to 1 or 50 to 1)

May be photocopied for student use.

Watt-Hour Meter Stator

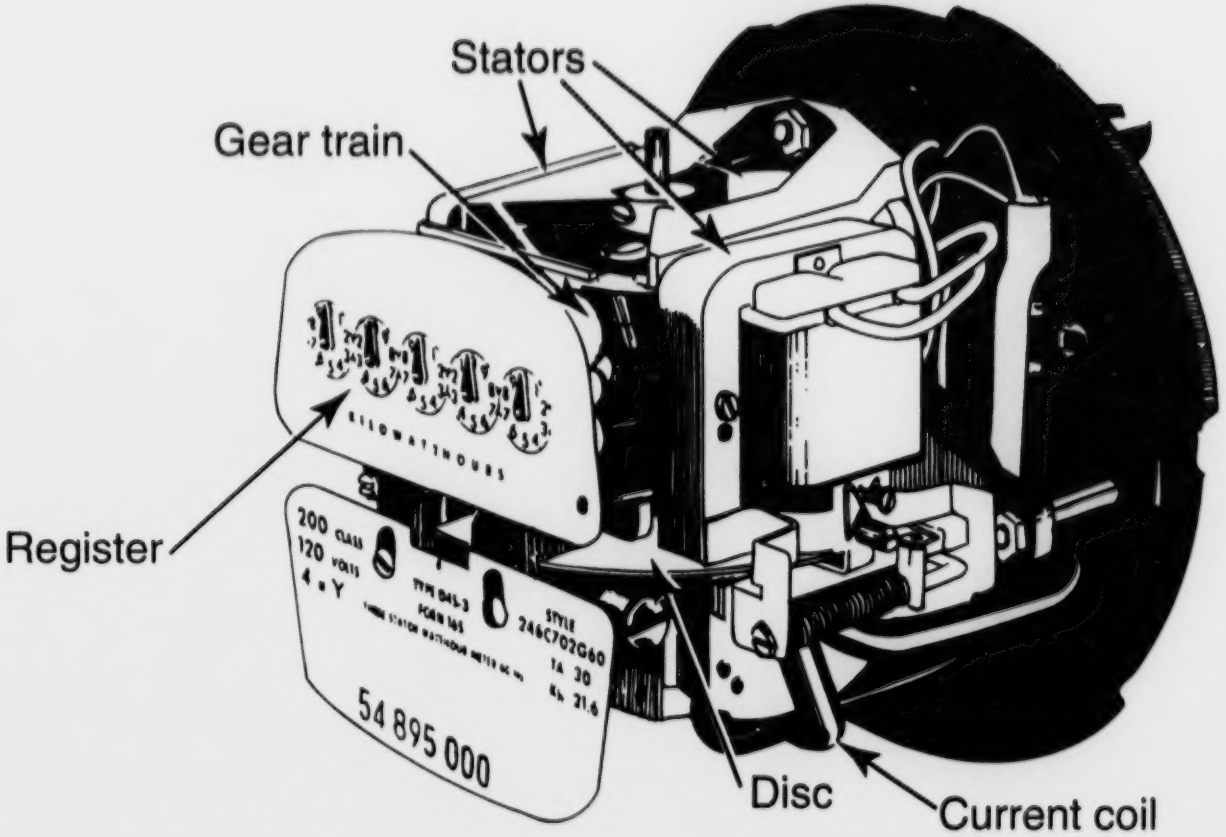


Potential Coil
Magnetic Flux

Current Coil
Magnetic Flux

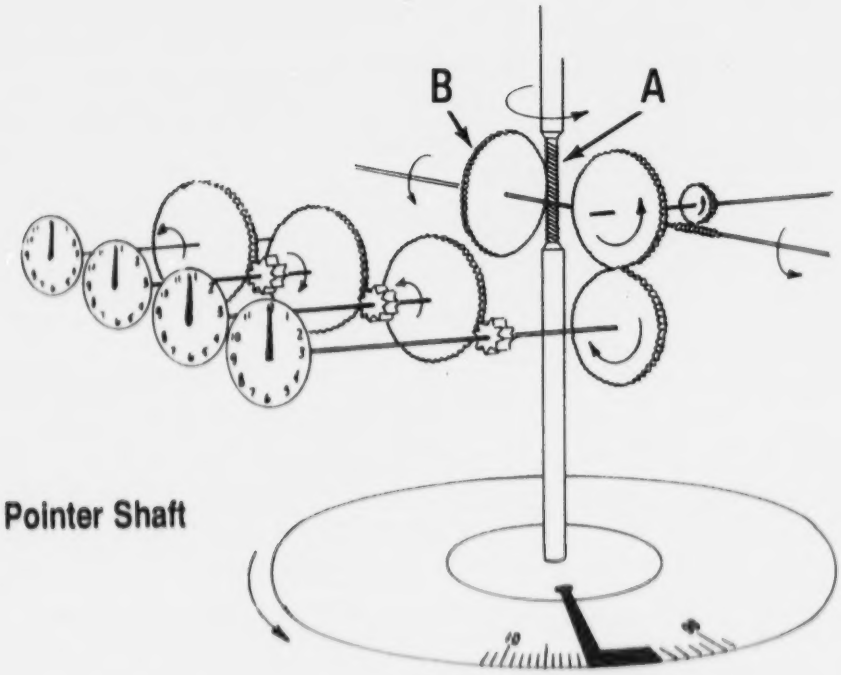
May be photocopied for student use.

Polyphase Meter



May be photocopied for student use.

Register Ratio

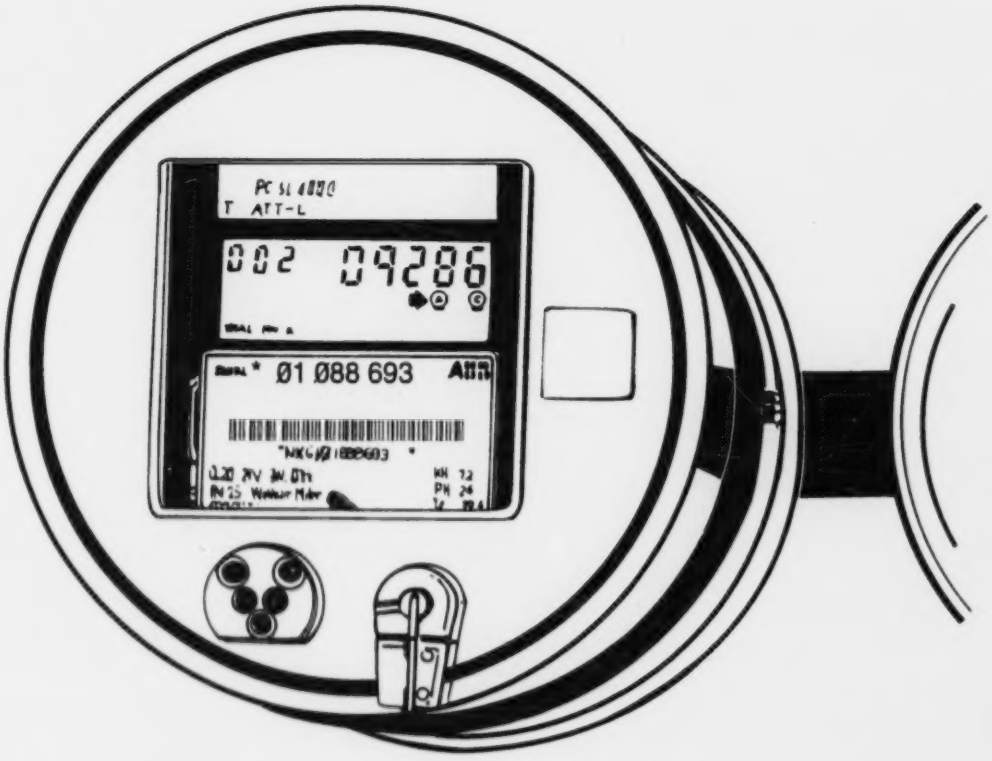


First Pointer Shaft

R_r Reduction From A To B

May be photocopied for student use

Digital Meter



TM 5

May be photocopied for student use.

METERS AND METER APPLICATION
UNIT 1

TEST

NAME _____ SCORE _____

1. Match terms commonly associated with metering on the right to the correct definitions. (Terms and definitions are continued on the following page. Answers for "a" through "m" are on this page.)

_____a.	Rate at which an electrical circuit performs work	1.	Demand
_____b.	Power multiplied by time	2.	Uni-directional register
_____c.	Instrument which measures electrical energy	3.	Watt-hour meter
_____d.	Gear train arranged to count the revolutions of a meter disc	4.	Damping system
_____e.	One watt for one hour	5.	Detent
_____f.	One thousand watts for one hour	6.	Power
_____g.	Stationary part of a meter which produces a magnetic flux that causes the meter disc to turn	7.	Kilowatt-hour
_____h.	Magnet or magnets which cause a retarding force on the meter disc	8.	Stator
_____i.	Power requirements (kW) over a period of time, usually 15 or 30 minutes	9.	Watt-hour
_____j.	Device installed on a meter to prevent meter from running backwards when current flow through the meter is reversed	10.	Energy
_____k.	Meter register which registers energy even if meter is installed upside down	11.	Register
_____l.	Small lamp that indicates the presence of voltage on the potential coil	12.	Polyphase meter
_____m.	Combination of single-phase meter stators in a single unit	13.	Potential indicator

May be photocopied for student use.

TEST

_____n. Maximum current-carrying capability of a meter

_____o. Meter which carries entire load of current through its current coils

_____p. Meter that is used with current transformers to measure electrical energy

_____q. Watt-hours per revolution of the meter disc

_____r. Ratio of revolutions of the first register shaft to each revolution of the first pointer shaft

_____s. Ratio of revolutions of the meter disc to one revolution of the first register shaft

_____t. Relationship of current flow through a current transformer to the output current

14. First reduction
15. Current transformer ratio
16. Transformer-rated meter
17. Self-contained meter
18. K_h (meter constant)
19. R_r (register ratio)
20. Class

2. List general types of meters.

a. _____

b. _____

c. _____

3. List types of meters by base construction.

a. _____

b. _____

4. List classes of meters and the current-carrying capacity of each.

a. _____

b. _____

c. _____

d. _____

May be photocopied for student use

TEST

5. Match meters to types of service. Complete each item.

   a. _____ service — Use two-wire meter

   b. Single-phase three-wire service — Use _____ meter

   c. _____ service — Use three-wire delta meter

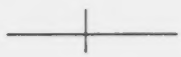
   d. _____ service — Use four-wire delta meter

   e. Three-phase four-wire _____ service — Use _____ meter

6. Match meter voltage ratings on the right to the correct types of service.

_____a.	Single-phase two-wire	1.	Phase-to-ground
_____b.	Single-phase three-wire	2.	Phase-to-phase
_____c.	Three-phase three-wire delta		
_____d.	Three-phase four-wire delta		
_____e.	Three-phase four-wire wye		

7. Match abbreviations and symbols used with metering circuit diagrams on the right to the correct meanings.

_____a.	Potential transformer (symbol)	1.	
_____b.	Ten pole test block	2.	
_____c.	Potential transformer	3.	
_____d.	Current transformer	4.	**PT**
_____e.	Delta connected	5.	**CT**
_____f.	Ground	6.	**C_1**
_____g.	Two-wire current transformer	7.	**P_1**
_____h.	Ground connection	8.	**G**
_____i.	Solid connection	9.	**N**
_____j.	Self-contained	10.	**SC**

May be photocopied for student use.

TEST

_____k. Three-wire current transformer

_____l. Transformer-rated

_____m. Neutral connection

_____n. Current connection

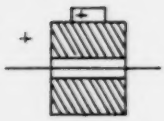
_____o. Seven pole test block

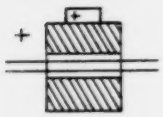
_____p. Wye connected

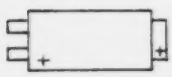
_____q. Potential connection

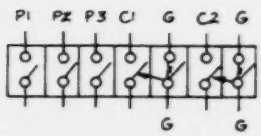
_____r. No connection

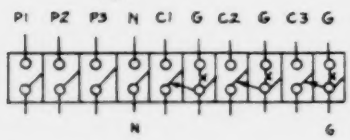
11. TR

12. 

13. 

14. 

15. 

16. 

17. △

18. Y

8. List uses of current transformer metering.

a. _____

b. _____

c. _____

_____

9. List uses of self-contained meters.

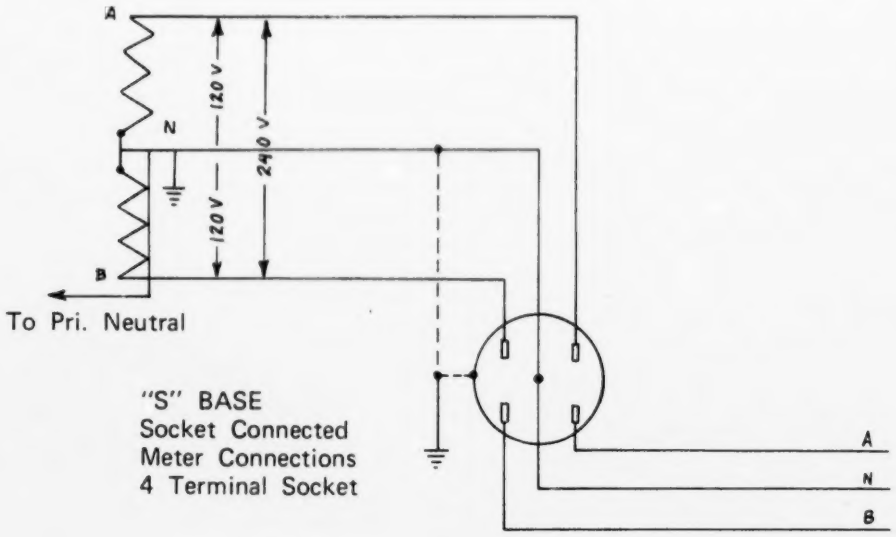
a. _____

b. _____

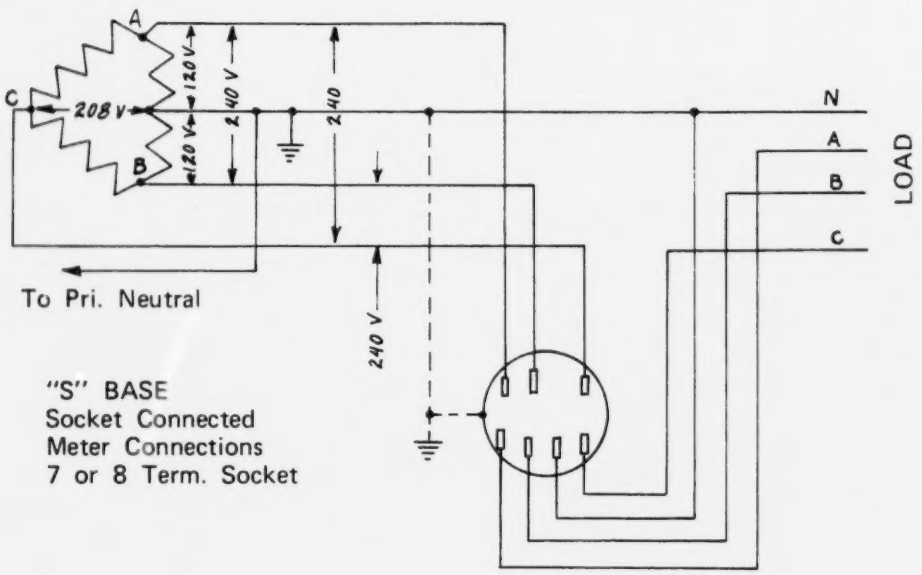
May be photocopied for student use.

TEST

10. Identify various self-contained meter connections.



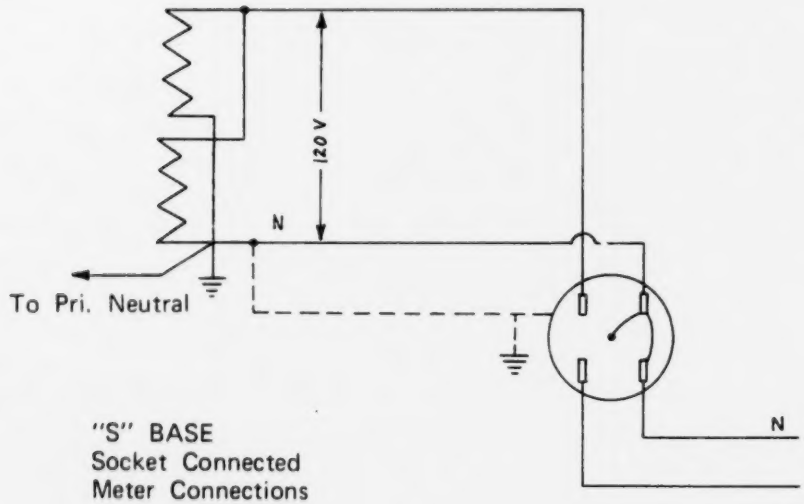
a. _____



b. _____

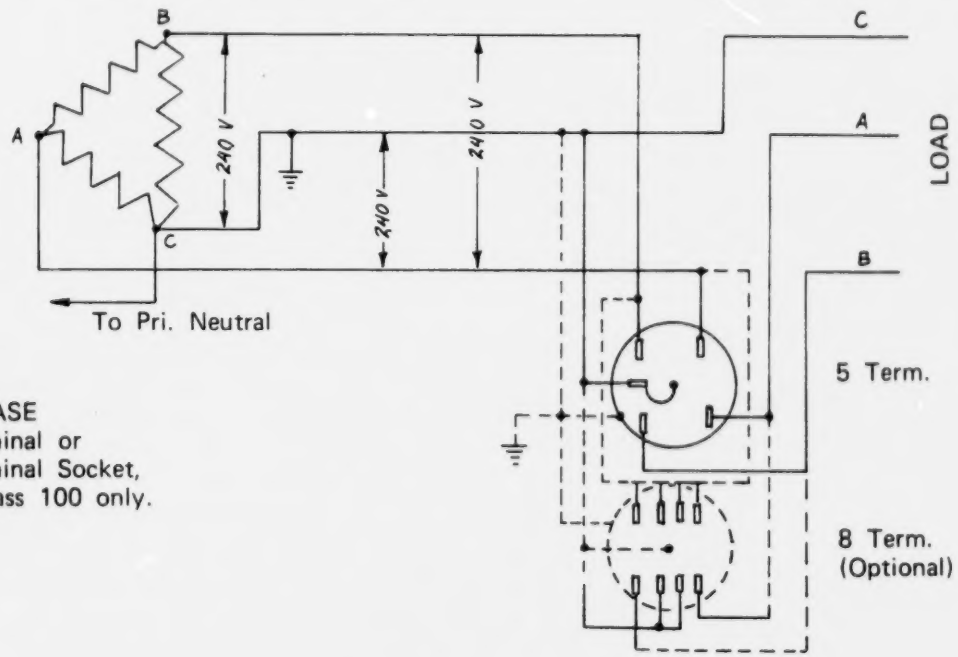
May be photocopied for student use.

TEST



"S" BASE
Socket Connected
Meter Connections
4 Terminal Socket

c. _____

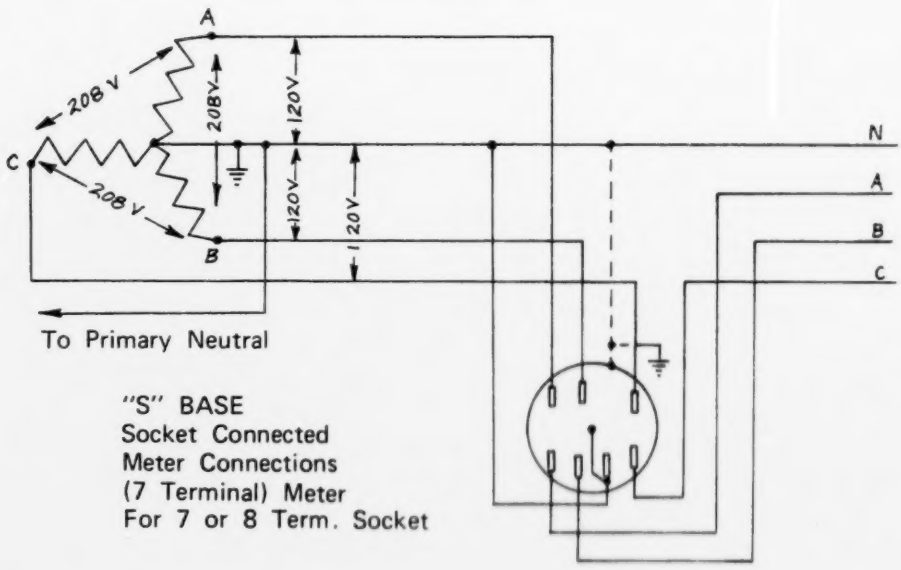


"S" BASE
5 Terminal or
8 Terminal Socket,
For Class 100 only.

d. _____

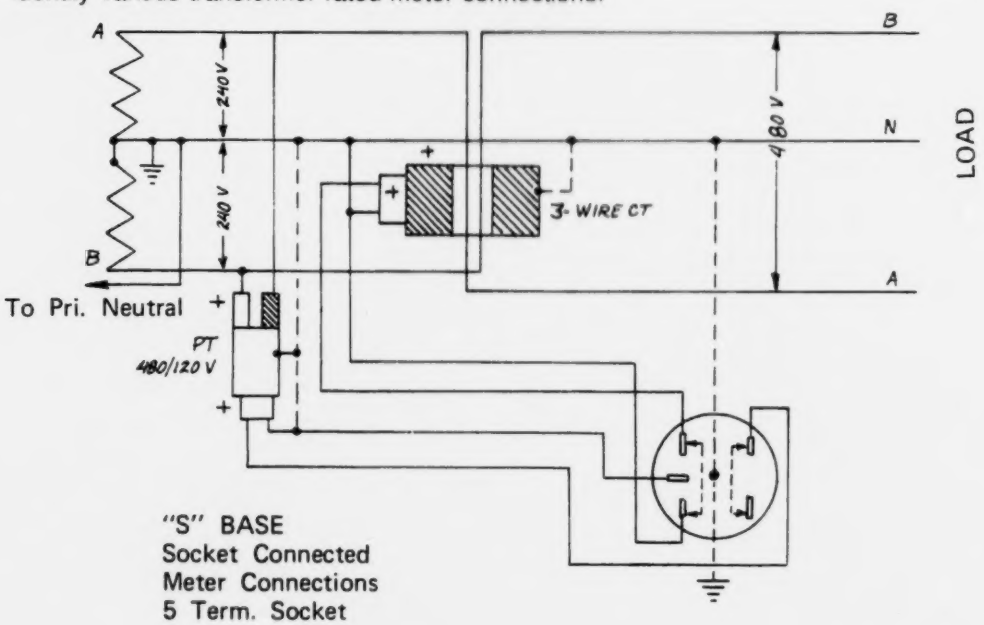
May be photocopied for student use.

TEST



e. _____

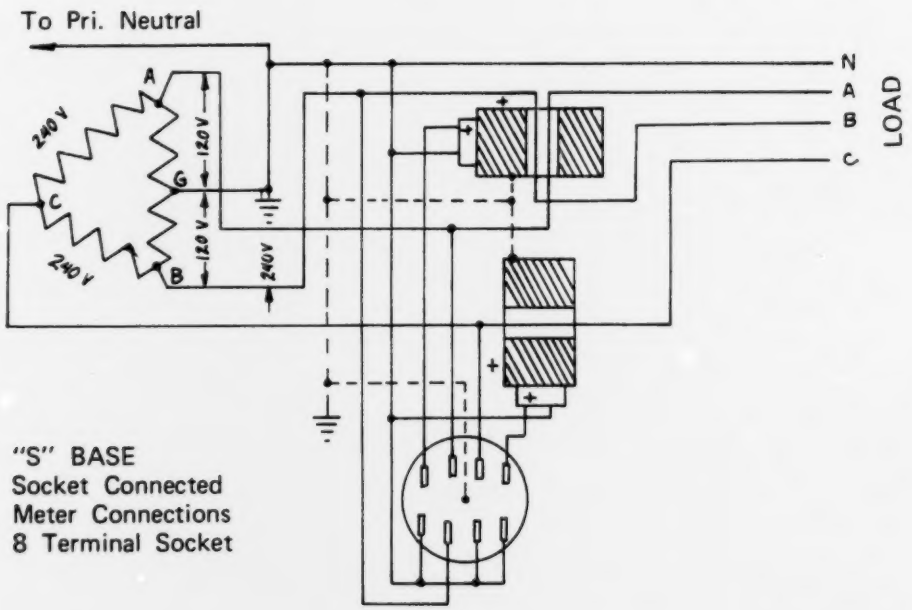
11. Identify various transformer-rated meter connections.



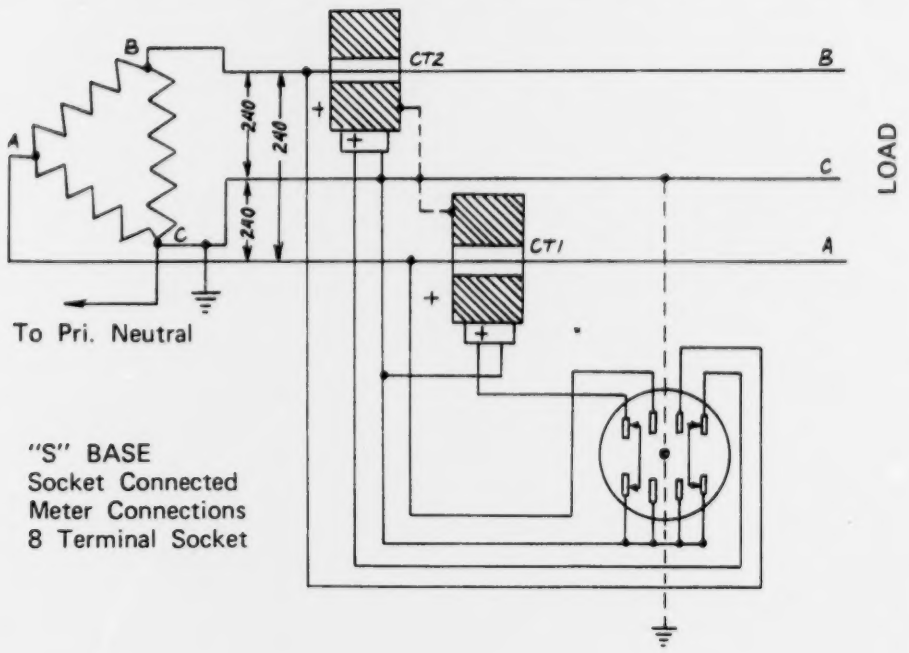
a. _____

May be photocopied for student use.

TEST



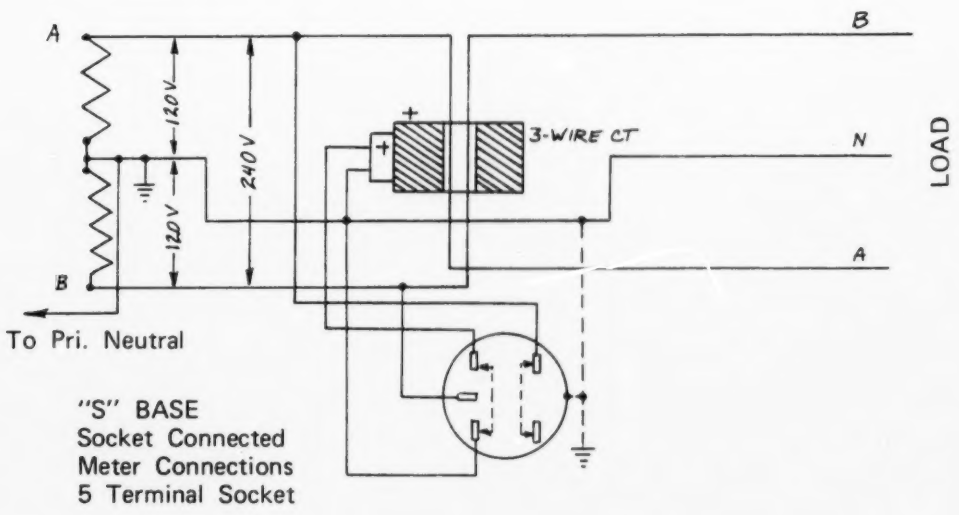
b. _____



c. _____

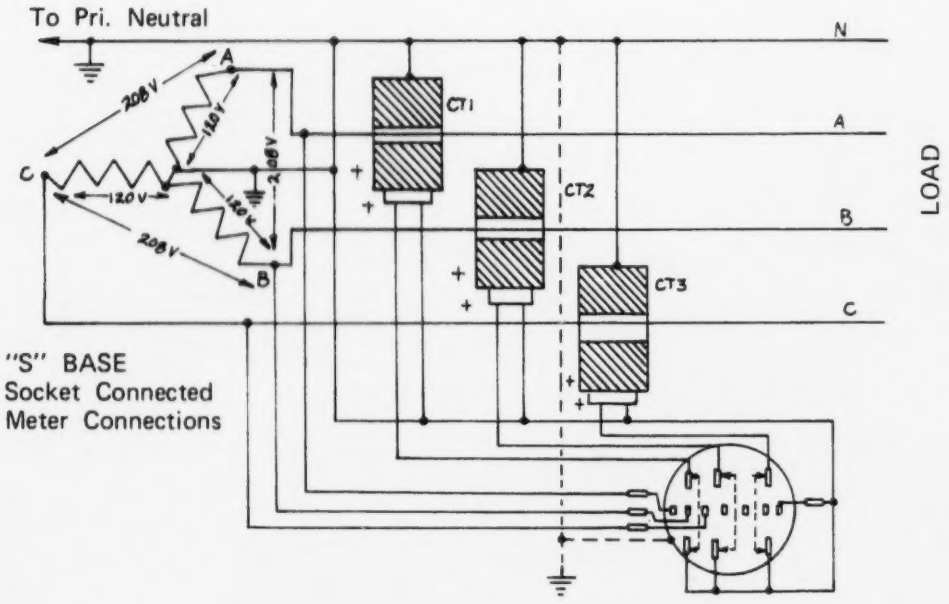
May be photocopied for student use.

TEST



"S" BASE
Socket Connected
Meter Connections
5 Terminal Socket

d. _____



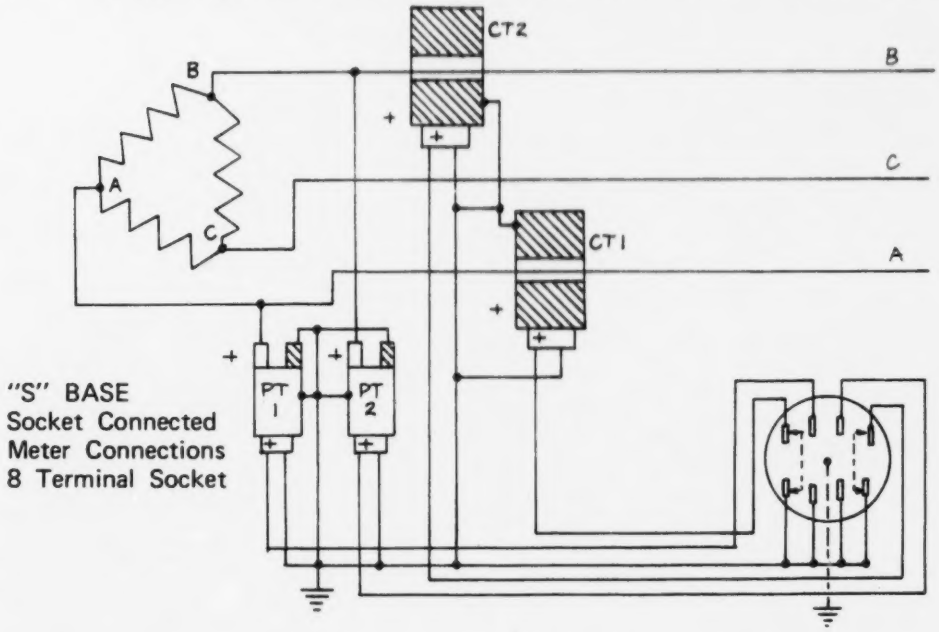
"S" BASE
Socket Connected
Meter Connections

e. _____

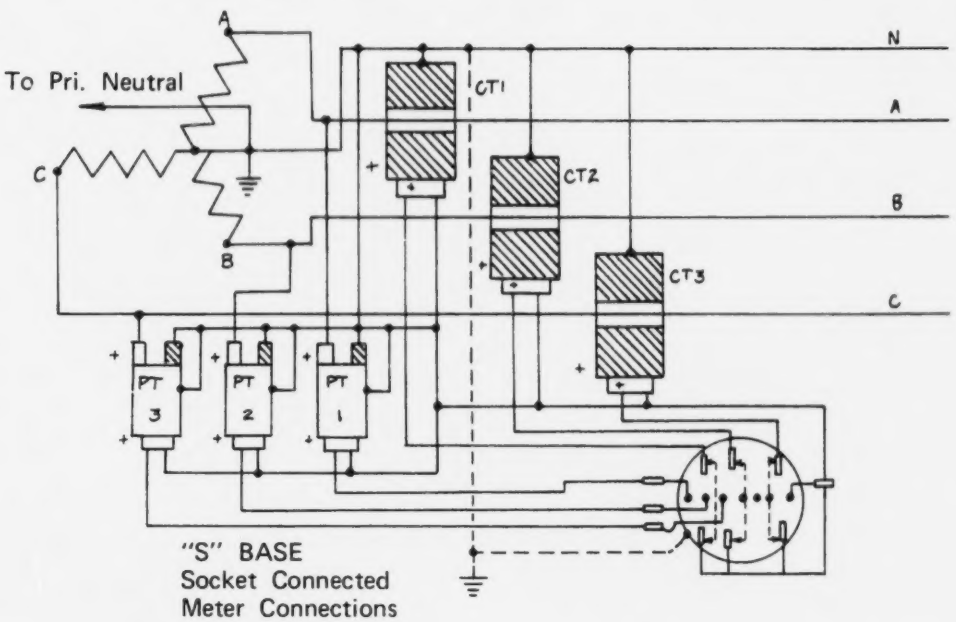
May be photocopied for student use.

TEST

12. Identify various transformer-rated meter connections for 600 volts or above.



a. _____



b. _____

May be photocopied for student use.

TEST

13. State the procedure for selecting the correct meter.

a. _____

b. _____

c. _____

d. _____

e. _____

14. List methods for determining voltage for wye and delta connected meters.

a. Wye-connected service — _____

_____

b. Delta-connected service — _____

_____

15. Match types of services on the right to specific uses.

_____a. Apartment complexes where both light and power loads may be heavy

_____b. Commercial and industrial areas where long circuit distances can be made with small conductor

_____c. Residences where three-phase power is needed for heating or air conditioning and industrial locations where small three-phase power is needed with large light loads

_____d. Most residences and small industrial locations

_____e. Billboards, shallow well pumps, and small dwellings

_____f. Power loads only for oil field and irrigation pumps

1. Three-wire three-phase 240 or 480 volt delta
2. Two-wire single-phase 120-volt service
3. Four-wire three-phase 120/240-volt delta
4. Three-wire single-phase 120/240 volt
5. Four-wire three-phase 277/480-volt wye
6. Four-wire three-phase 120/208-volt wye

May be photocopied for student use.

TEST

16. List types of meters which have multipliers.

a. _____

b. _____

17. Arrange in order the correct procedure for determining meter multipliers by placing a "1" before the first procedure, a "2" before the second procedure, and so on.

_____a. Record first gear reduction given by meter manufacturer

_____b. Multiply meter constant x register ratio x **CT** ratio x **PT** ratio x first gear reduction and divide product by 10,000

_____c. Record information from meter nameplate and meter register, K_h and R_r

_____d. Record ratios from current transformer and potential transformer

18. List precautions to observe with metering.

a. _____

_____

b. _____

_____

c. _____

_____

d. _____

_____

19. Evaluated on Assignment Sheet 1.

20. Evaluated on Assignment Sheet 2.

May be photocopied for student use

SYSTEM KNOWLEDGE
UNIT 2

SUGGESTED ACTIVITIES

1. Suggested activities for the instructor:

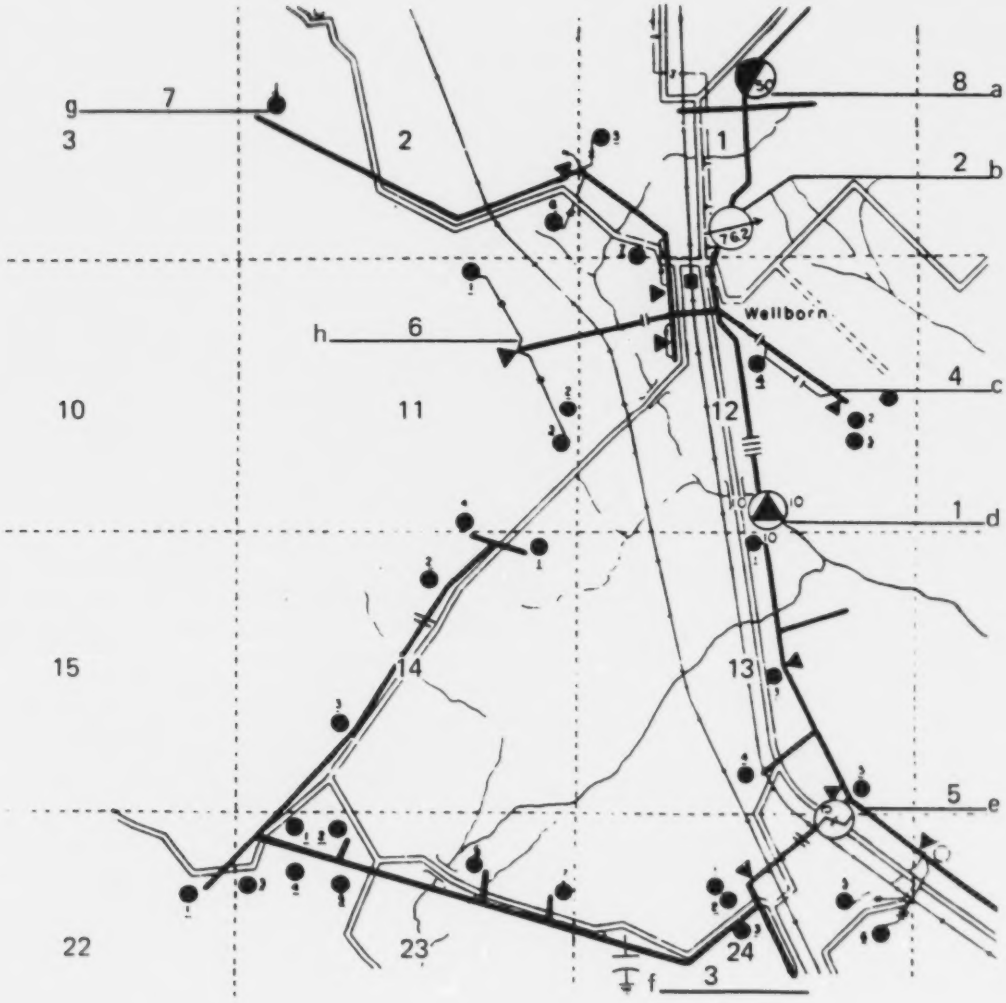
   - Provide student with objective sheet.
   - Provide student with information and assignment sheet.
   - Discuss unit and specific objectives.
   - Discuss information and assignment sheet.
   - Give test.

2. Unit references:

   - *Power Line Technician.* Stillwater, OK: Oklahoma Department of Vocational and Technical Education, Curriculum and Instructional Materials Center, 1978.

SYSTEM KNOWLEDGE
UNIT 2

ANSWERS TO ASSIGNMENT SHEET



SYSTEM KNOWLEDGE
UNIT 2

ANSWERS TO TEST

1. a. 3 e. 2
   b. 6 f. 4
   c. 1 g. 5
   d. 7

2. a. 10 m. 8 y. 21
   b. 13 n. 15 z. 26
   c. 2 o. 16 aa. 33
   d. 4 p. 14 bb. 36
   e. 3 q. 17 cc. 34
   f. 11 r. 18 dd. 32
   g. 1 s. 25 ee. 30
   h. 5 t. 20 ff. 28
   i. 7 u. 23 gg. 31
   j. 12 v. 24 hh. 27
   k. 6 w. 22 ii. 35
   l. 9 x. 19 jj. 29

3. a. 3 g. 10 m. 13 s. 24 y. 23
   b. 7 h. 9 n. 15 t. 19
   c. 6 i. 1 o. 14 u. 18
   d. 2 j. 4 p. 16 v. 21
   e. 8 k. 11 q. 17 w. 22
   f. 5 l. 12 r. 20 x. 25

ANSWERS TO TEST

4. a. Federal highway
   b. State road
   c. County road
   d. Unimproved road
   e. Railroad (with station)
   f. Telephone and telegraph line
   g. Bridge
   h. Cities and towns (within corporate limits)
   i. Towns and villages
   j. State capital
   k. County seat
   l. Houses and other buildings
   m. School

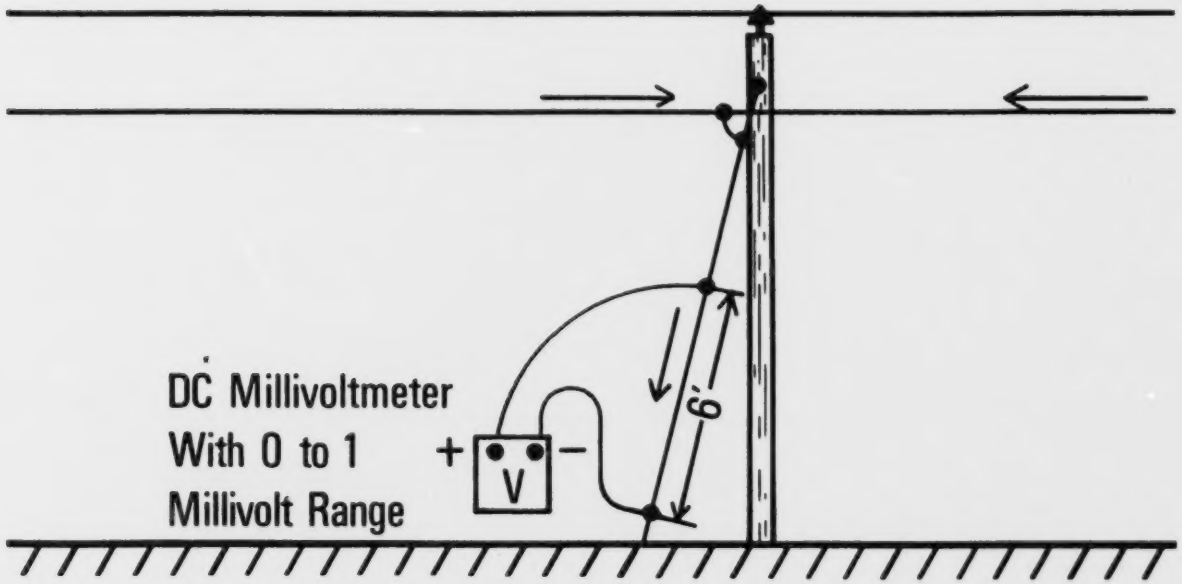
5. (NOTE: Any three of the following are acceptable.)
   a. Switches transmission line feed when a fault occurs
   b. Switches capacitors on and off the line
   c. Starts and connects generator to line when outage occurs
   d. Connects distribution circuits together during peak loads

6. a. Know the locations of all automated equipment on the system
   b. Know the functions of all automated equipment on the system
   c. Be able to override or disconnect automated equipment when necessary

7. a, b, c, e, f

8. Evaluated on Assignment Sheet 1.

Determination Of Galvanic Current From Voltage Drop Along A Guy



May be photocopied for student use.

Transposition

May be photocopied for student use

SYSTEM KNOWLEDGE
UNIT 2

TEST

NAME _____ SCORE _____

1. Match terms used with system knowledge on the right to the correct definitions.

_____a. Location where one or more line voltage capacitors are installed

_____b. Equipment that operates switches on capacitor, primary line, and other equipment without manual assistance

_____c. Current that flows through a conductor when a fault occurs on a circuit line

_____d. Corrosion of anchor rods and other underground equipment caused by the flow of direct current to the neutral conductor and returning to earth through the underground equipment

_____e. Ampacity of the conductors that distribute power from a substation

_____f. Transformer bank which is energized by phases which have sources in different directions or possibly fed from different substations

_____g. Location in the primary or transmission line where the phases change positions

1. Fault current
2. Feeder capacity
3. Capacitor station
4. Multi-feed bank
5. Phase transposition
6. Automated equipment
7. Galvanic action

May be photocopied for student use.

TEST

2. Define symbols used with overhead lines and equipment identification on system maps. Write the correct number in each blank. (Symbols and meanings are continued on the following pages. Answers to "a" though "m" are on this page.)

_____a. Consumer receiving electrical service

_____b. 1∅ primary line

_____c. V∅ primary line

_____d. 3∅ primary line

_____e. Transformer

_____f. Primary, secondary underbuild

_____g. Secondary construction (bare)

_____h. Transformer bank 3∅△ rating KVA (system-owned)

_____i. Transformer bank 3∅△ rating KVA (consumer-owned)

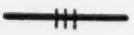
_____j. Transformer bank 3∅Y ,rating KVA (system-owned)

_____k. Transformer bank 3∅Y , rating KVA (consumer-owned)

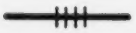
_____l. Transformer bank 3∅ (open △)

_____m. Transformer bank 3∅ (open Y)

1.

2. 

3.

4. 

5.

6.

7.

8.

9.

10.

11.

12.

13.

May be photocopied for student use.

TEST

_____n. Normally open point

_____o. Fused cut-out, rating (single shot)

_____p. Fused cut-out, rating (2 shot)

_____q. Fused cut-out, rating (3 shot)

_____r. Automatic circuit recloser, rating

_____s. Automatic line sectionalizer, rating

_____t. Voltage regulator, rating, KVA

_____u. Minimum and maximum fault current

_____v. Air break switch (ganged)

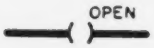
_____w. Disconnect switch

_____x. Capacitor bank-series, rating

_____y. Capacitor bank-shunt, rating

_____z. Capacitor bank-shunt, switched

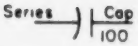
14.

15. 

16.

17.

18.

19. 

20.

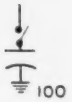
21.

22.

23.

24.

25.

26. 

May be photocopied for student use.

TEST

_____aa. Metering point, capacity

_____bb. Substation (indicate voltage and transformer size)

_____cc. Substation, 3-phase transformer (indicate voltage, transformer size, and winding)

_____dd. Oil circuit breaker (station type)

_____ee. Generating plant, capacity

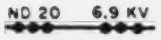
_____ff. Distribution line (existing)

_____gg. Other distribution line, voltage in kV, and name of utility

_____hh. Transmission line, existing, voltage, and system designation

_____ii. Transmission line, proposed

_____jj. Transmission line, voltage, and name (other utilities)

27. 

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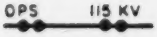
29. 

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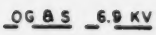
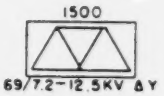
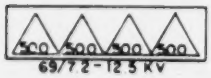
31. 

32.

33.

34. 

35.

36. 

May be photocopied for student use.

TEST

3. Define symbols used with underground lines and equipment identification on system maps. Write the correct number in each blank. (Symbols and meanings are continued on the following page. Answers for "a" through "m" are on this page.)

_____a. Transformer, underground

_____b. Pedestal, above ground or surface mounted

_____c. Pedestal, underground

_____d. Splice (nonseparable)

_____e. T-tap (nonseparable)

_____f. Elbow terminator

_____g. Bushing plug

_____h. Parking stand (insulated)

_____i. Parking stand (grounded)

_____j. UM 3-02 (2 point load break connection)

_____k. UM 3-11 (1 point load break, 1 point termination)

_____l. UM 3-03 (3 point load break)

_____m. UM 3-12 (2 point load break, 1 point termination)

1.

2.

3.

4.

5.

6.

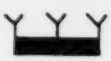
7.

8.

9.

10.

11.

12. 

13.

May be photocopied for student use.

TEST

_____n. UM 3-21 (1 point load break, 2 point termination)

_____o. Fault indicator

_____p. Cable in conduit

_____q. Single-phase primary

_____r. V-phase primary

_____s. Three-phase primary

_____t. Single-phase primary riser

_____u. V-phase primary riser

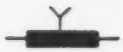
_____v. Three-phase primary riser

_____w. Secondary or service (3 wire)

_____x. Secondary or service (4 wire)

_____y. Transformer, surface mounted

14.

15. 

16.

17.

18.

19.

20.

21.

22.

23.

24.

25.

May be photocopied for student use

TEST

4. Identify symbols used to locate cultural features on system maps.

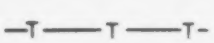
a. _____

b. _____

c. _____

d. _____

e. _____



f. _____

g. _____

h. _____

i. _____

j. _____

k. _____

l. _____

m. _____

5. List three of the functions of automated equipment.

a. _____

_____

b. _____

_____

c. _____

_____

May be photocopied for student use.

TEST

6. List precautions to observe with automated equipment.

   a. _____

   _____

   b. _____

   _____

   c. _____

   _____

7. Select from a list conditions associated with system terrain. Place an "X" in front of the correct conditions.

   _____a. Areas of limited access

   _____b. Road conditions during wet weather

   _____c. Areas where blasting may be required to construct lines

   _____d. Areas of rapid brush growth

   _____e. Soil conditions throughout the system

   _____f. Areas where special equipment may be required to obtain access

8. Evaluated on Assignment Sheet 1.

May be photocopied for student use.

TRANSFORMER CONNECTIONS AND BANKING
UNIT 3

SUGGESTED ACTIVITIES

1. Suggested activities for the instructor:

   - Provide student with objective sheet.
   - Provide student with information and assignment sheets.
   - Make transparencies.
   - Discuss unit and specific objectives.
   - Discuss information and assignment sheets.
   - Give test.

2. Unit references:

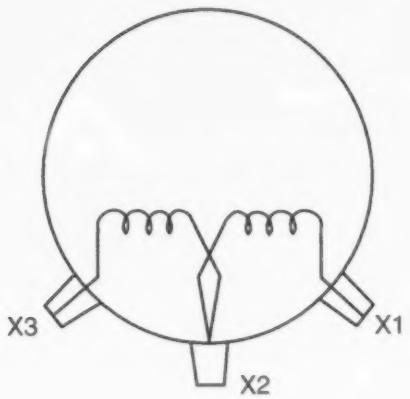
   - *ABB Distribution Transformer Guide.* Distribution Transformer Division. Athens, Georgia and Jefferson City, Missouri., Revised 1995.
   - *Power Line Technician.* Stillwater, OK: Oklahoma Department of Vocational and Technical Education, Curriculum and Instructional Materials Center, 1978.

TRANSFORMER CONNECTIONS AND BANKING
UNIT 3

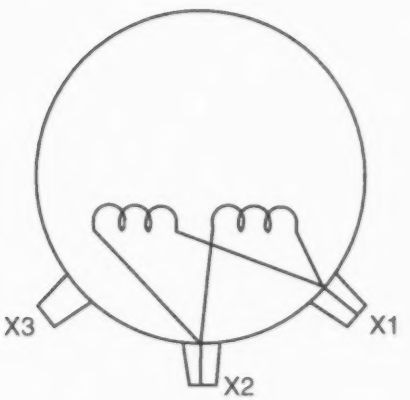
ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet 1

1. Series

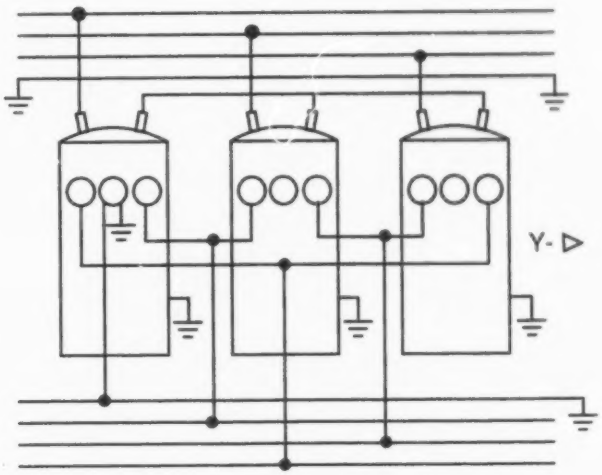


2. Parallel

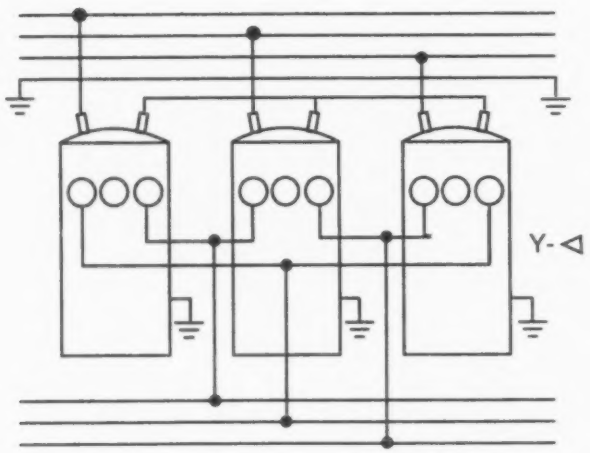


ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet 2

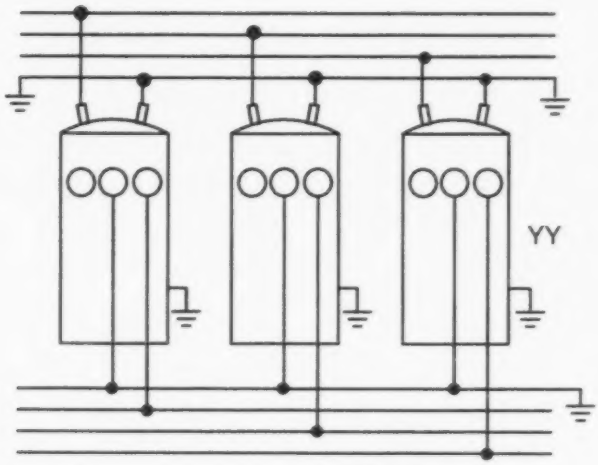


Assignment Sheet 3

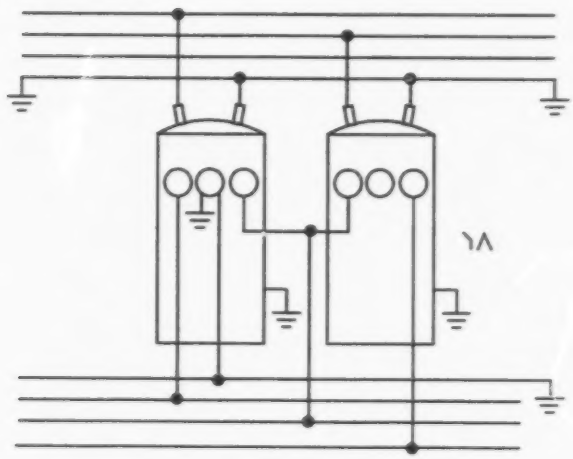


ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet 4

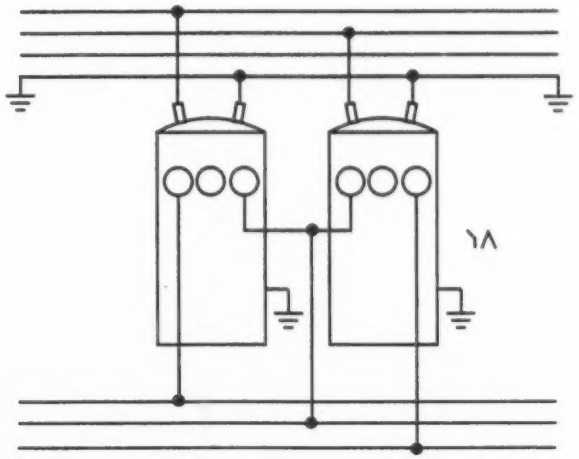


Assignment Sheet 5

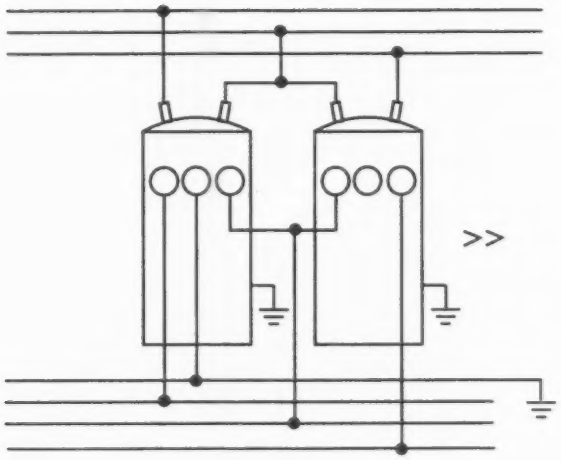


ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet 6

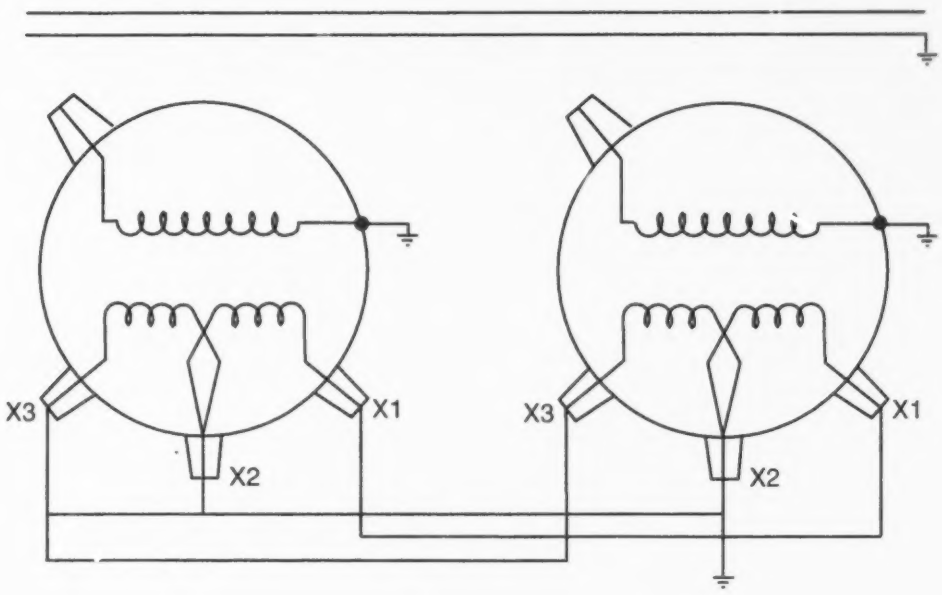


Assignment Sheet 7



ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet 8



TRANSFORMER CONNECTIONS AND BANKING
UNIT 3

ANSWERS TO TEST

1. a. 3 e. 6
   b. 1 f. 4
   c. 2 g. 5
   d. 8 h. 7
2. a. An identical voltage appears on the other winding
   b. In phase
   c. in the opposite direction
   d. "H1," "X1"
3. a. 4 e. 8
   b. 3 f. 7
   c. 5 g. 1
   d. 2 h. 6
4. a. the kVA and primary voltage
   b. No, only to the location of the secondary bushings.
5. a. Strictly from the location of the LV or secondary bushings
   b. Because the location of "H1" is arbitrary
6. a. Parallel connected for 120-volt two-wire service subtractive polarity
   b. Parallel connected for 120-volt two-wire service additive polarity
   c. Series connected for 120/240-volt three-wire service
7. a. Two-bushing primary connection
   b. Single-bushing primary connection
   c. Two single-bushing transformers paralleled

ANSWERS TO TEST

8. a. Open-wye primary

   b. Open-delta secondary

   c. Open-delta primary

   d. Open-delta secondary

   e. Open-delta primary

   f. Open-delta secondary

9. a. Identify the secondary phases corresponding to the primary phases so that the phase relationship is maintained according to ANSI Standards.

   b. Balance mechanical loading on the pole, usually by placing the heaviest transformer in the center of the cluster.

   c. Minimize the complexity of secondary and primary bus connections whenever possible.

10. a. 2

    b. 4

    c. 1

    d. 6

    e. 5

    f. 3

11. a. A "phasor diagram" schematically shows the phase relations between the various bushings.

    b. 0°, "X1" lags "H1" by 30°

12. a. Wye primary

    b. Wye secondary

    c. Delta primary

    d. Delta secondary

    e. Wye primary

    f. Delta secondary

ANSWERS TO TEST

g. Wye primary

h. Delta secondary

13.
- Check the polarity marked on nameplate
- Check primary voltage rating
- Check secondary voltage rating
- Place tap changers on same position on transformers to be banked or paralleled
- Match the impedance on each of the transformers

14. a. 240

b. 120

c. 120

d. 240

e. 120

15.
- Connect phase to ground
- Connect phase to phase

16. a. 3

b. 4

c. 1

d. 2

17.
- Consider all primary and secondary parts energized unless primary and secondary of all transformers are disconnected
- Open disconnect switches to remove secondary load before energizing transformer

18. Evaluated on Assignment Sheet 1.

19. Evaluated on Assignment Sheet 2.

20. Evaluated on Assignment Sheet 3.

21. Evaluated on Assignment Sheet 4.

22. Evaluated on Assignment Sheet 5.

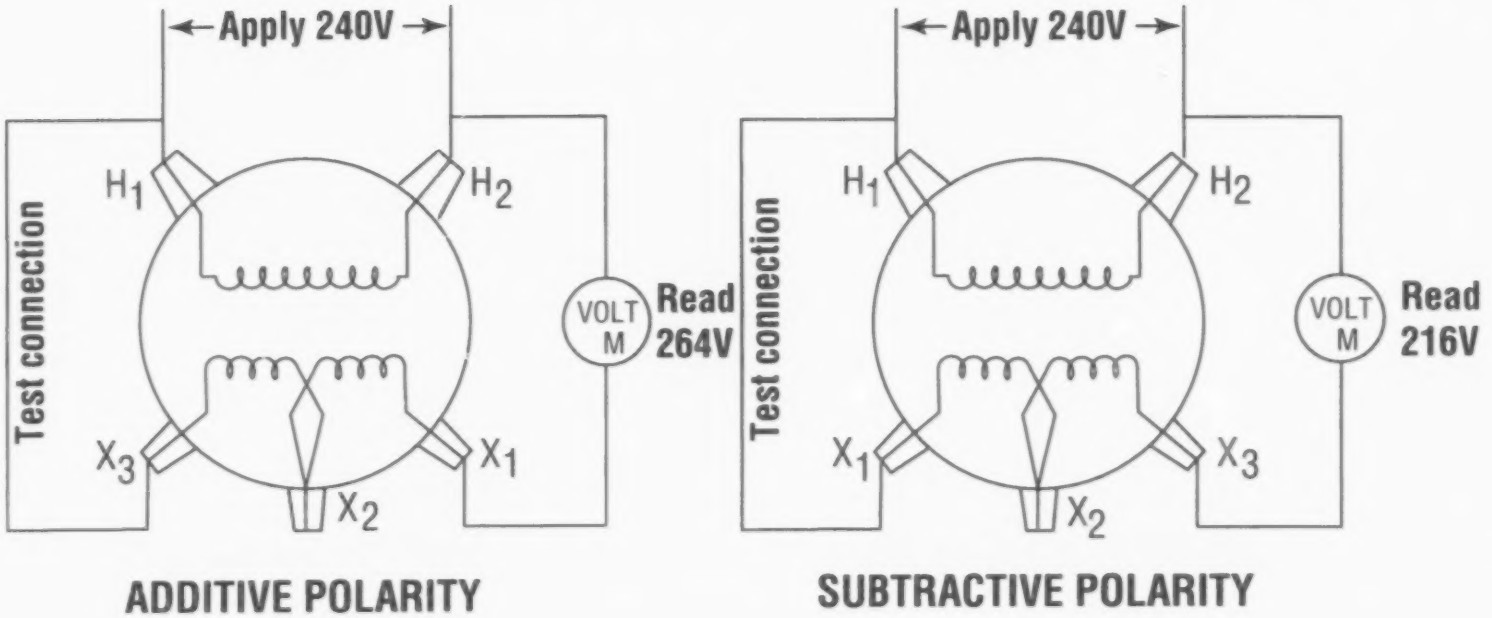
ANSWERS TO TEST

23. Evaluated on Assignment Sheet 6.

24. Evaluated on Assignment Sheet 7.

25. Evaluated on Assignment Sheet 8.

Transformer Polarity



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Transformers of different polarity may be banked by changing either the primary or secondary leads on one transformer.

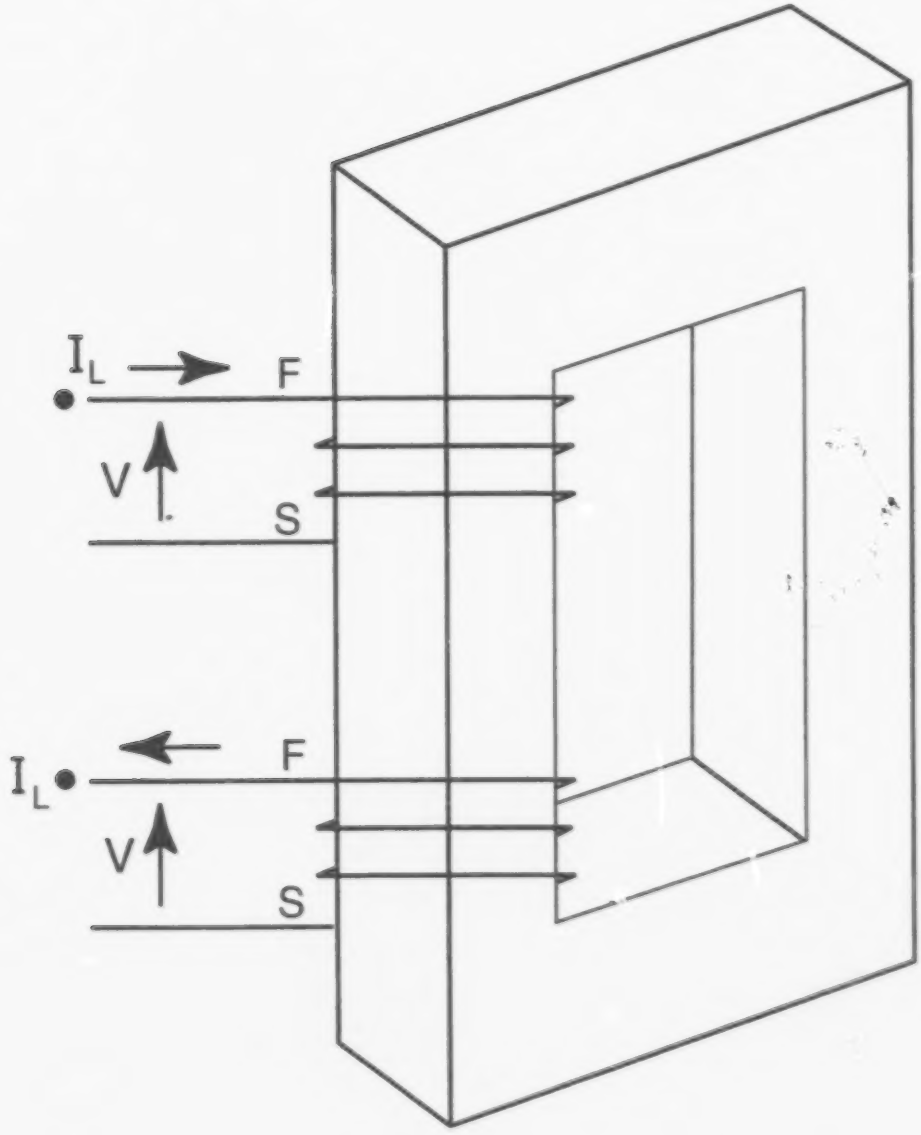
TM 1

PLT E - 3 - 13

S1

S2

Transformer Construction



TM 2

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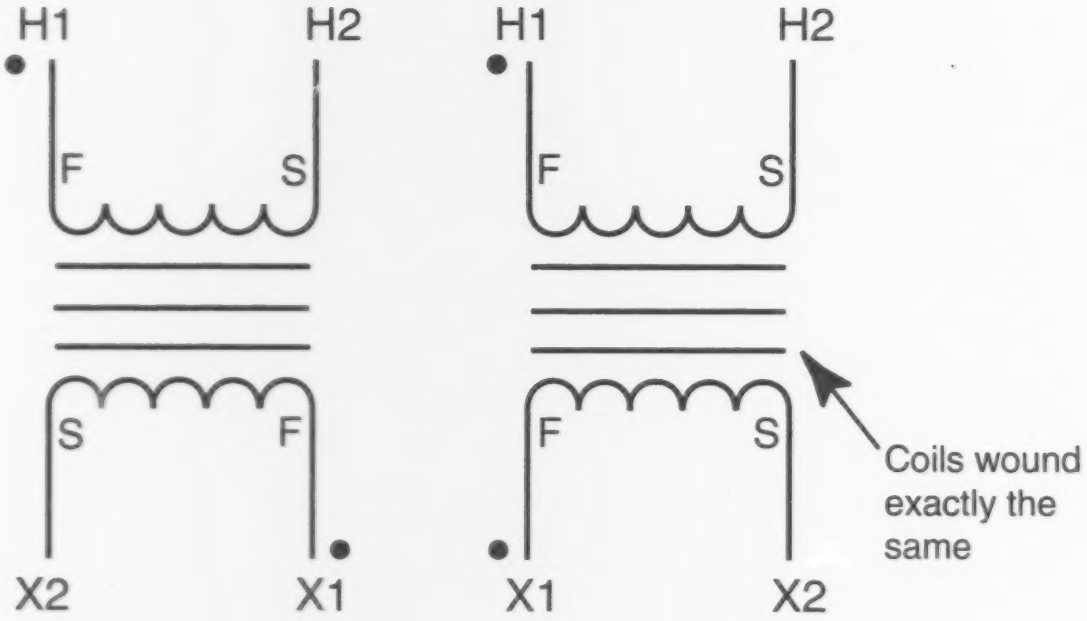
Polarity Differences
Single Phase



ADDT POL (< =8660V & < =200KVA

SUBT POL (>8660V or >200KVA

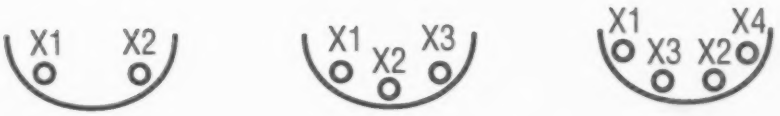
TM 3

May be photocopied for student use.

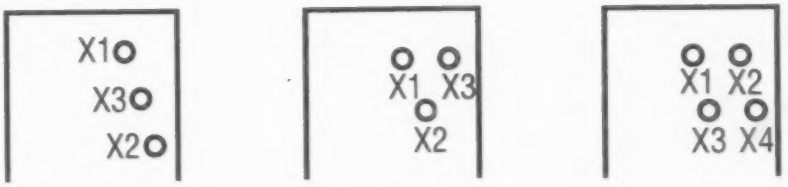
Bushing Locations on Padmounts

Subtractive:

Pole-type

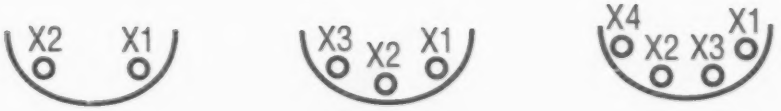


Padmount

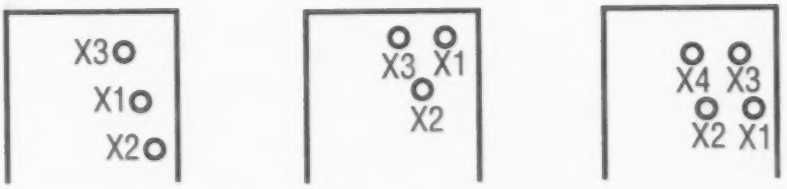


Additive:

Pole-type



Padmount



TM 4

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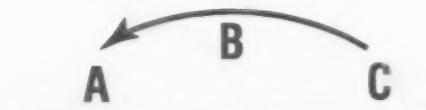
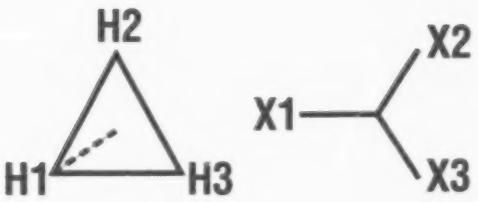
Phasor Diagrams for 3Ø

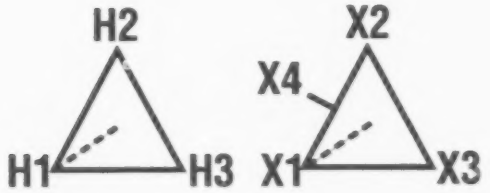


Counter-clockwise rotation
i.e., 'B' lags 'A' by 120°

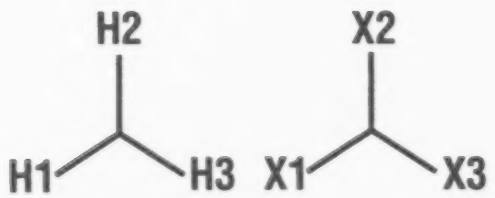
Δ - Y



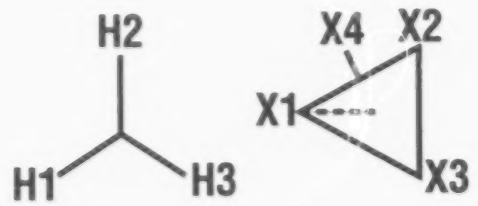
Δ - Δ



Y - Y



Y - Δ



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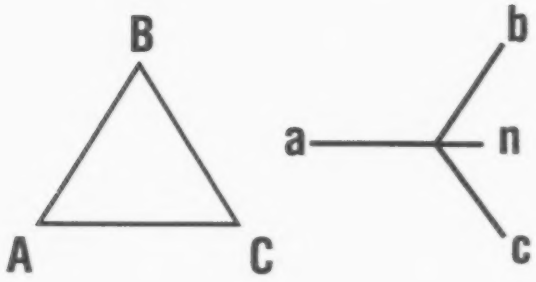
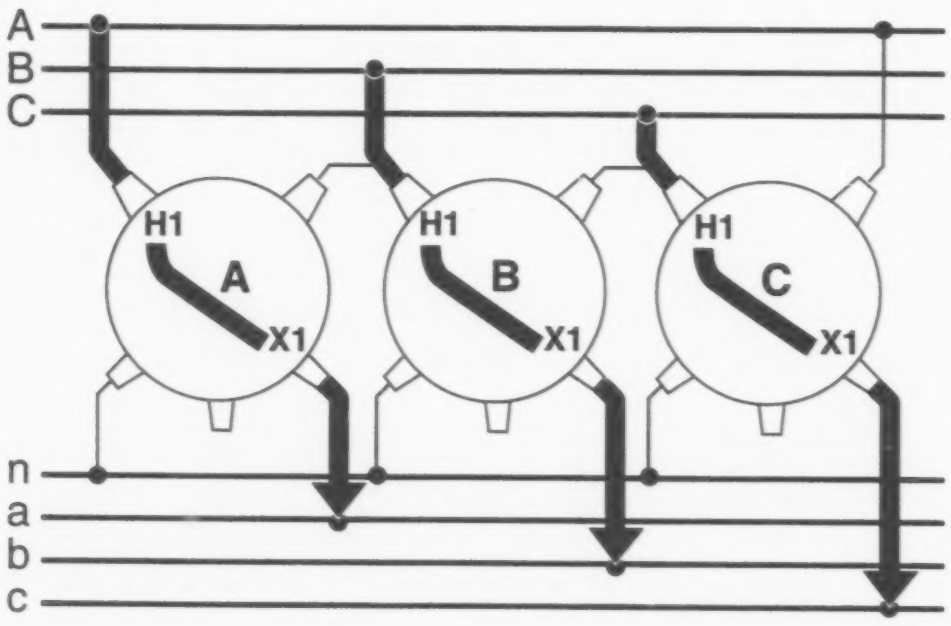
DELTA-WYE-ADDITIVE





TM 6

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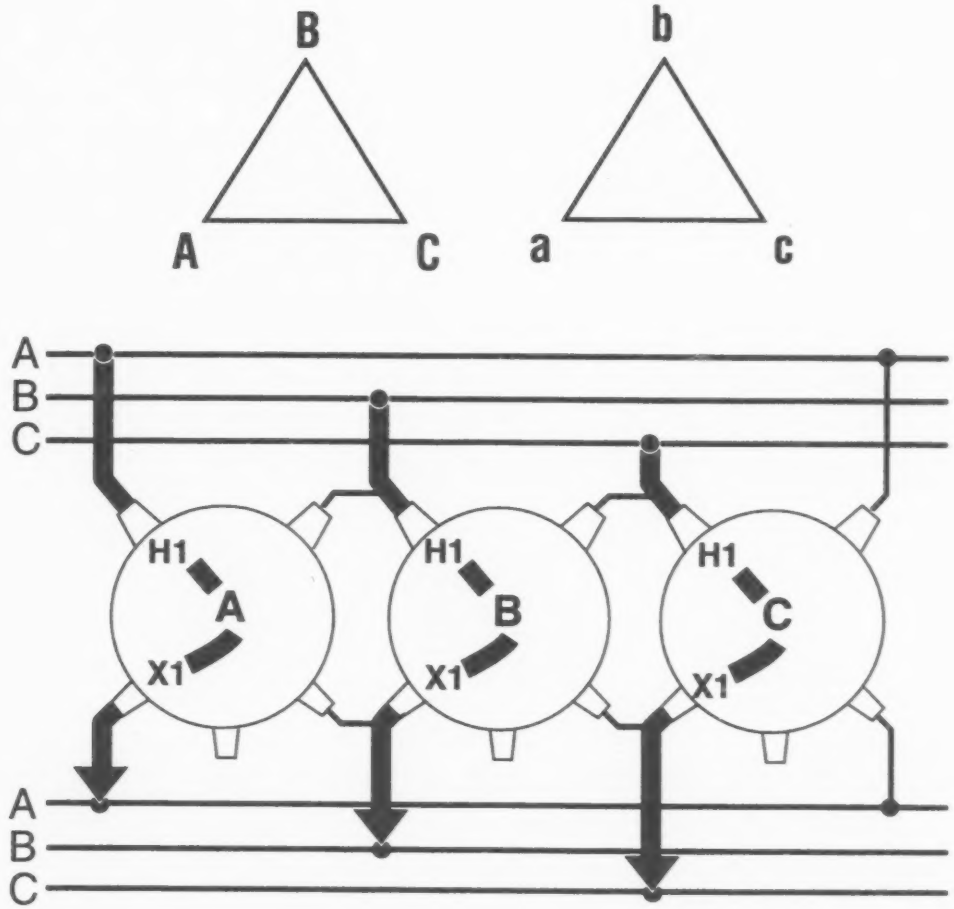
DELTA-DELTA-SUBTRACTIVE



TM 7

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TRANSFORMER CONNECTIONS AND BANKING
UNIT 3

TEST

NAME _____ SCORE _____

1. Match terms commonly used with transformer connections and banking on the right to the correct definitions.

_____a. Designation of relative voltage phase and purely a function of how the leads are brought out of a transformer

_____b. Instantaneous voltages of the two transformer windings add to each other when connected in sequence

_____c. Instantaneous voltages of the two transformer windings subtract from each other when connected in sequence

_____d. Symbol (Δ) used to identify the diagrams that describe a system using three transformers whose secondary windings are connected in series

_____e. Symbol (Y) used to identify diagrams that describe a system using three transformers whose secondary windings are paralleled

_____f. Symbol (Λ) used to identify a connection that uses two transformers for a three-phase service

_____g. Term used to identify the high voltage leg of a four-wire delta-connected secondary

_____h. Combined effect of resistance and inductive reactance

_____i. A winding that can only be used for a phase-to-ground connection

1. Additive polarity
2. Subtractive polarity
3. Polarity
4. Open delta
5. Wild leg
6. Star or wye
7. Impedance
8. Delta
9. GRDY

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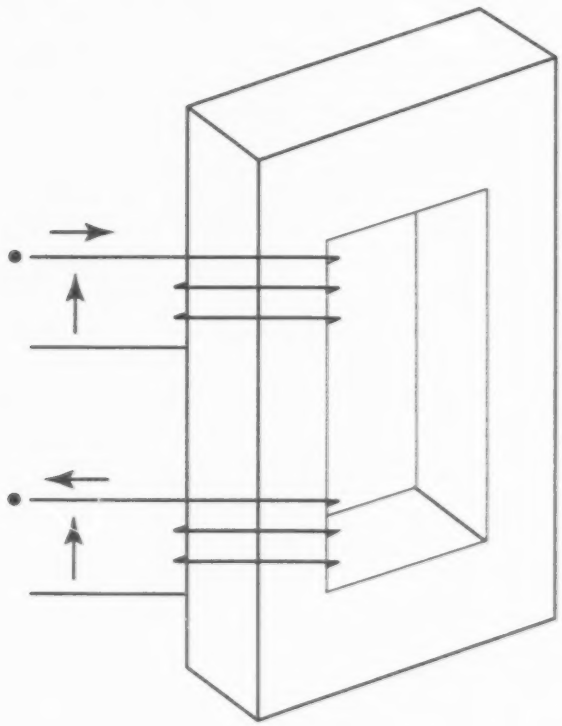
TEST

2. Define characteristics of transformer construction. Study the figure, then write (on the line below each item) the answer to the question or the word(s) completing the statement.



a. When two identical coils are wrapped around an iron core and 60 Hz voltage is applied to one winding, *what appears* on the other winding?

_____

b. When the finish end of each winding is identified with a dot, the voltages at the dotted terminals are _____.

_____

c. When a current is drawn from the second winding, another current must also flow in the first winding in *what direction*?

_____

May be photocopied for student use

TEST

d. In practical transformers, polarity dots are not used, but corresponding terminals are marked _____ and _____ for the primary and secondary terminals whose voltages are in phase.

_____

3. Match symbols used with transformer voltage rating and connection diagrams on the right to the correct meanings.

_____a.	Separates voltage rating of high side and low side windings	1.	H_0
		2.	Y
_____b.	Separates tap voltage and voltage rating of one winding	3.	/
_____c.	Separates windings that may be connected in parallel or series	4.	—
		5.	X
_____d.	Indicates a winding suitable for phase-to-ground connection	6.	X_0
_____e.	Indicate high voltage connections	7.	X_1, X_2, X_3, and X_4
_____f.	Indicate low voltage connections	8.	H_1, H_2, and H_3
_____g.	Indicates the primary ground or common connection		
_____h.	Indicates the secondary ground connection		

4. Discuss transformer polarities. Answer each question in the space provided.

a. The use of different polarity standards depends on *what*?

_____

b. Does polarity make a difference to the internal construction of a modern transformer? Please explain.

_____

_____

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TEST

5. Discuss bushing locations in relationship to polarity on padmount transformers and compare to pole-type in regard to subtractive and additive. Answer each question in the space provided.

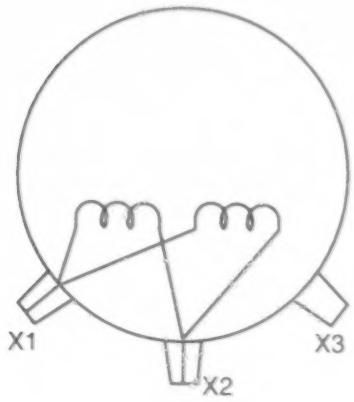
   a. How is the polarity of padmounts determined?

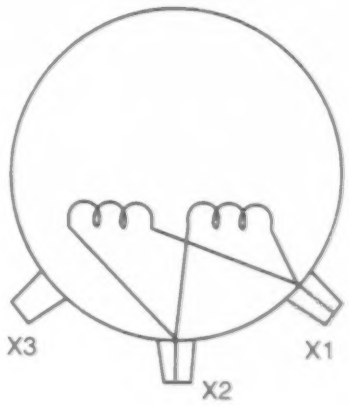
   _____

   b. Why is polarity completely defined by the relative positions of the LV bushings?

   _____

6. Identify the following secondary coil connections for two- and three-wire service.





a. _____ b. _____

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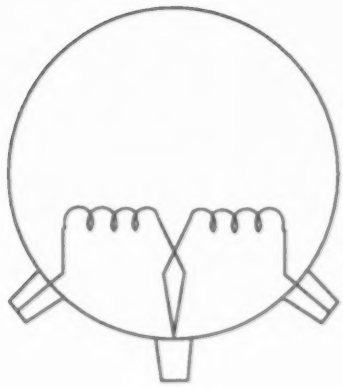
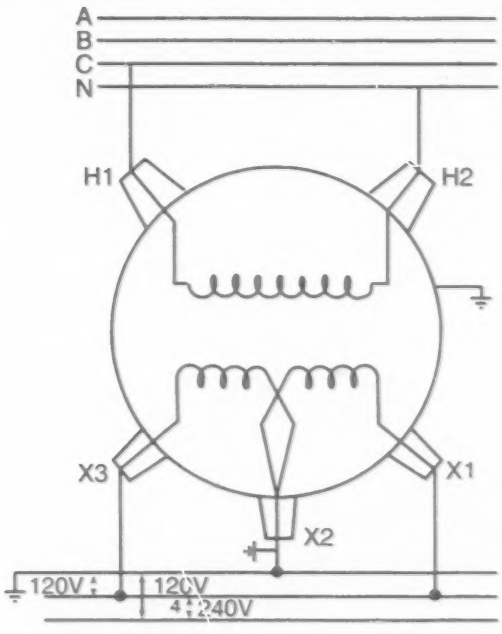
TEST



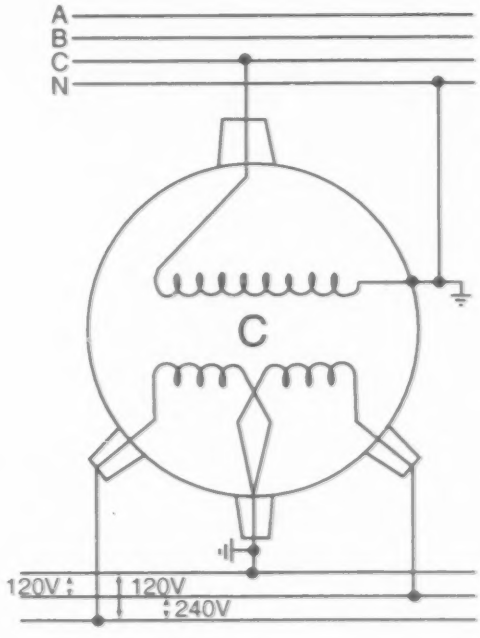
c. _____

7. Identify the following single-transformer connections for three-wire service.



a. _____

_____



b. _____

_____

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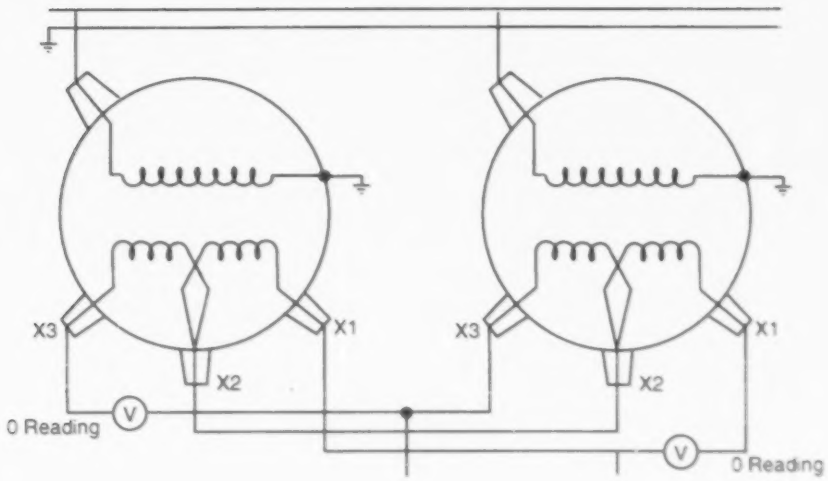
TEST



c. _____

_____

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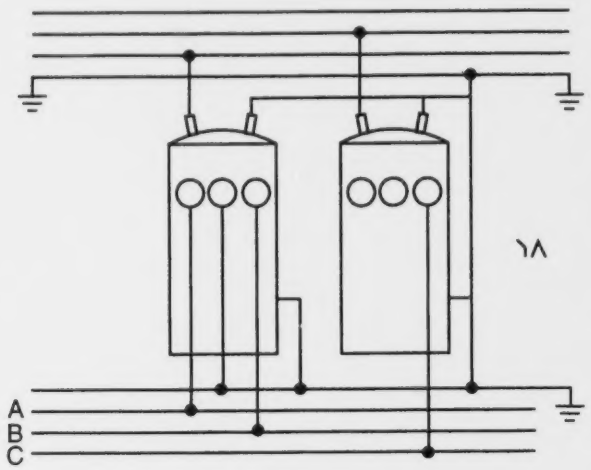
TEST

8. Identify the following two-transformer banks by stating the types of primary and secondary connections.



a. _____ primary

b. _____ secondary

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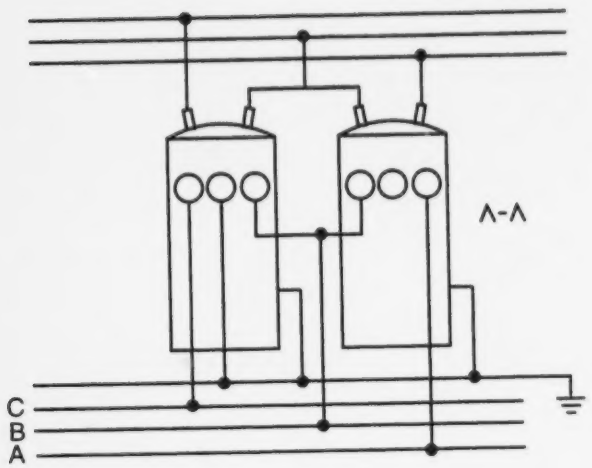
TEST



c. _____ primary

d. _____ secondary

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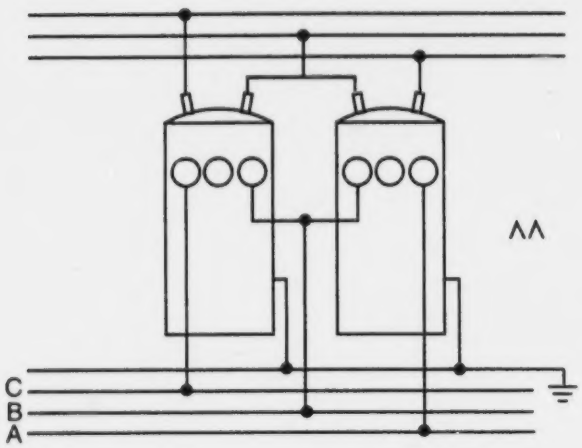
TEST



e. _____ primary

f. _____ secondary

9. Define objectives an electrician must keep in mind when constructing three-phase banks.

a. ANSI standards — _____

_____

b. Mechanical loading — _____

_____

c. Complexity of bus connections — _____

_____

10. List in order the step-by-step process for designing three-phase banks. Place a "1" before the first step, a "2" before the second step, and so on.

_____a. Determine primary phase to carry the heaviest load and primary phase rotation.

_____b. When secondary connection is WYE, and primary connection is DELTA, assign a phase to each single-phase transformer.

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TEST

_____c. Determine three-phase and single-phase loads to select type of bank connection and kVA size of each transformer.

_____d. When one transformer does not match the polarity of the other two, switch primary H1 and H2 leads.

_____e. Place transformer to supply single-phase load in leading position for OPEN DELTA secondaries.

_____f. When secondary connection is DELTA, assign a phase to each single-phase transformer.

11. Describe phase relationships between the bushings in three-phase banks. Answer the questions in the spaces provided.

a. What is the purpose of a phasor diagram?

_____

_____

b. What is the phase difference between "H1" and "X1" in WYE-WYE and DELTA-DELTA connections? In WYE-DELTA and DELTA-WYE connections?

_____

_____

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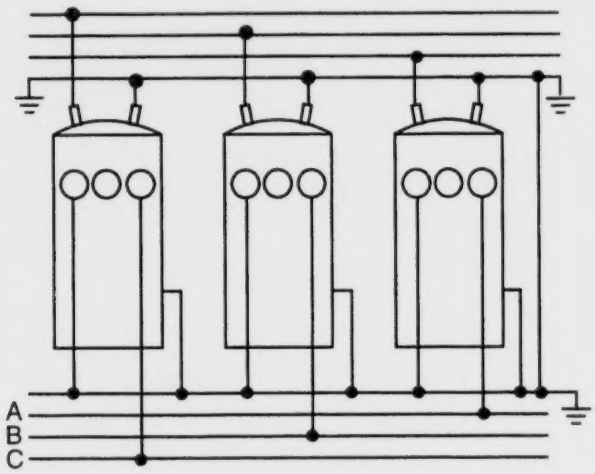
TEST

12. Identify the following types of primary and secondary connections for three-transformer banks.



a. _____ primary

b. _____ secondary

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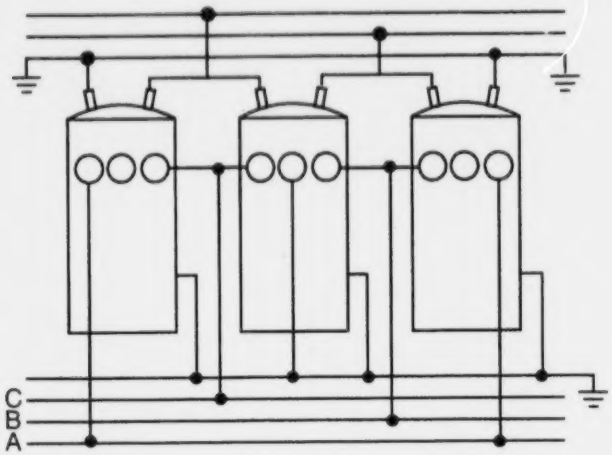
TEST

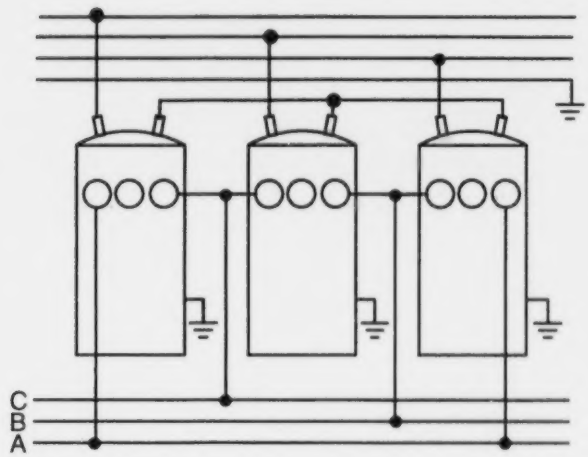


c. _____ primary

d. _____ secondary

May be photocopied for student use.

TEST

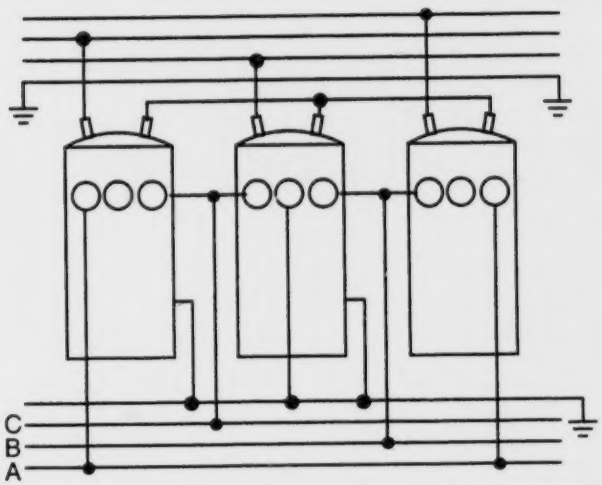


e. _____ primary

f. _____ secondary

May be photocopied for student use.

TEST



g. _____ primary

h. _____ secondary

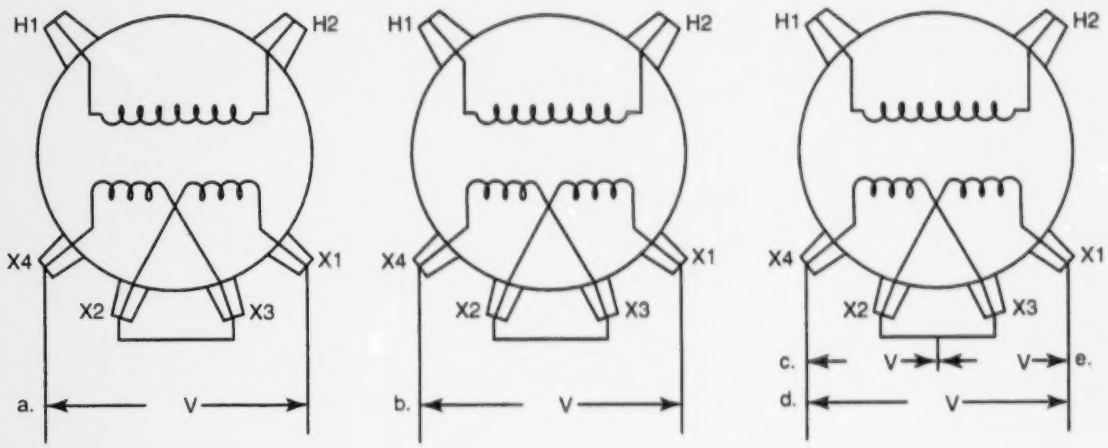
13. List five precautions to observe when selecting transformers to be banked or paralleled.

- _____
- _____
- _____
- _____
- _____

May be photocopied for student use.

TEST

14. Identify the following four-bushing transformers by stating the voltage produced from each connection.



a. _____ d. _____

b. _____ e. _____

c. _____

15. State the correct method of connecting the following WYE and DELTA transformers to a primary line.

- 12470 Grd Y/7200 — _____
- 13,800 — _____

16. Arrange in proper order the following steps to find a faulted transformer in a bank. Place a "1" before the first step, a "2" before the second step, and so on.

_____a. Disconnect primary and secondary leads

_____b. Connect each transformer as a single unit and check secondary voltage

_____c. Observe high side fuses for blown fuse

_____d. Check secondary voltage phase to phase

May be photocopied for student use.

TEST

17. State the precautions to observe with transformer banks.

- _____
  _____
  _____
- _____
  _____
  _____

18. Evaluated on Assignment Sheet 1.

19. Evaluated on Assignment Sheet 2.

20. Evaluated on Assignment Sheet 3.

21. Evaluated on Assignment Sheet 4.

22. Evaluated on Assignment Sheet 5.

23. Evaluated on Assignment Sheet 6.

24. Evaluated on Assignment Sheet 7.

25. Evaluated on Assignment Sheet 8.

May be photocopied for student use.

PHASING
UNIT 4

SUGGESTED ACTIVITIES

1. Suggested activities for instructor:

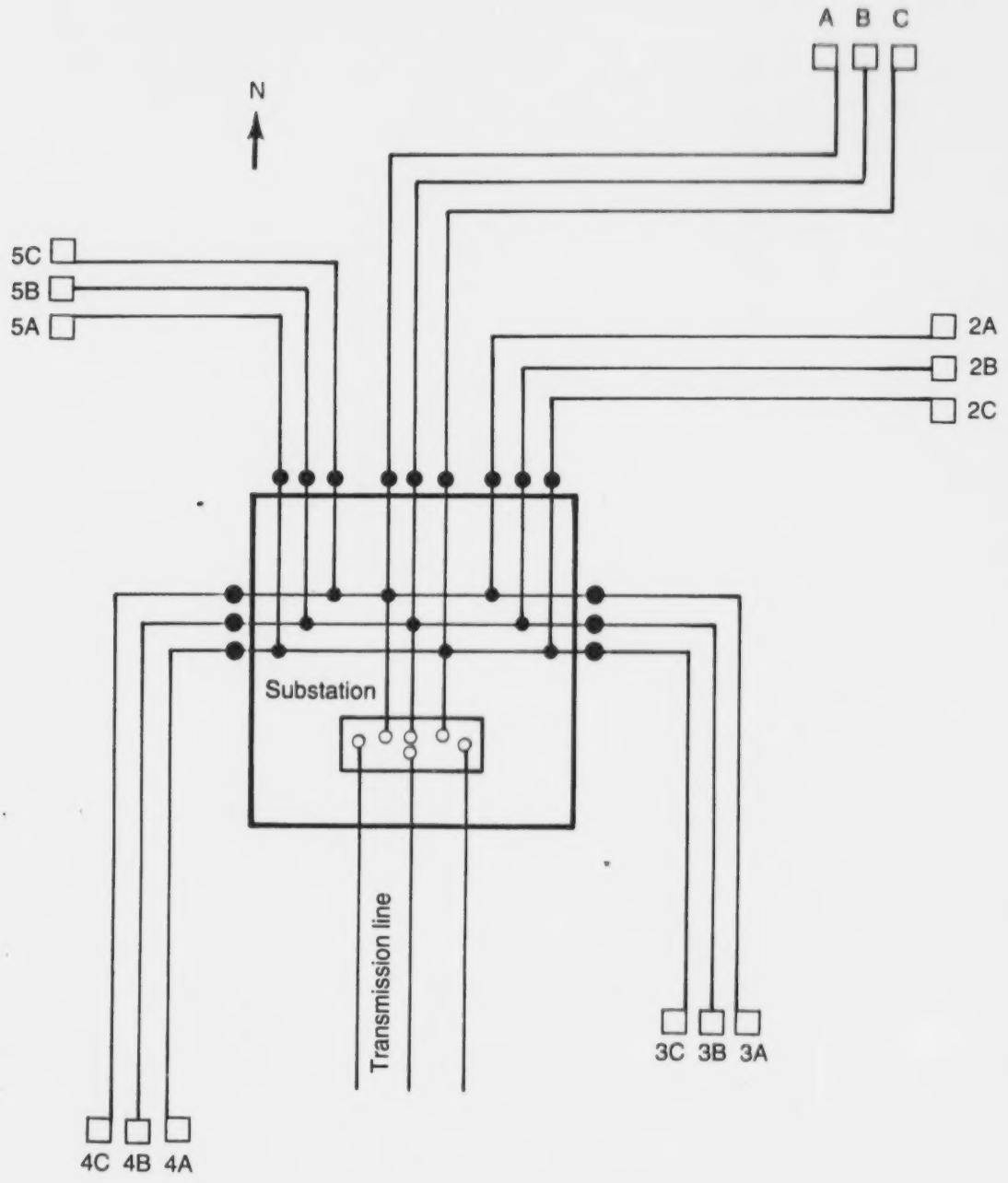
   - Provide student with objective sheet.
   - Provide student with information and assignment sheet.
   - Make transparencies.
   - Discuss unit and specific objectives.
   - Discuss information and assignment sheet.
   - Give test.

2. Unit references:

   - *Power Line Technician.* Stillwater, OK: Oklahoma Department of Vocational and Technical Education, Curriculum and Instructional Materials Center, 1978.

PHASING
UNIT 4

ANSWERS TO ASSIGNMENT SHEET

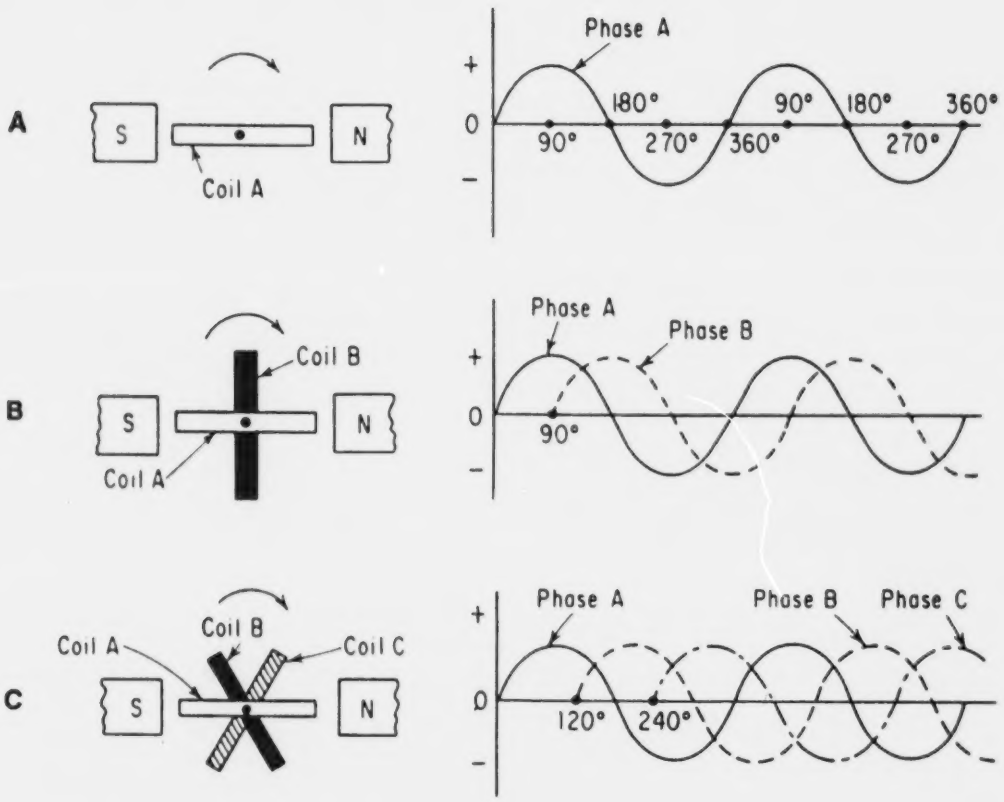


PHASING
UNIT 4

ANSWERS TO TEST

1. a. 2 e. 1
   b. 6 f. 4
   c. 5 g. 8
   d. 3 h. 7
2. a. Identifying distribution phases
   b. Phasing distribution circuits
   c. Determining phase sequence
3. a. Connect a phase sequence indicator to a three-phase circuit
   b. Check the direction of rotation of a three-phase motor
4. Interchange any two phases either on the primary or secondary side of the transformer bank
5. a. 3
   b. 2
   c. 1
   d. 5
   e. 4
6. a. 3
   b. 5
   c. 2
   d. 1
   e. 4
7. Evaluated on Assignment Sheet 1

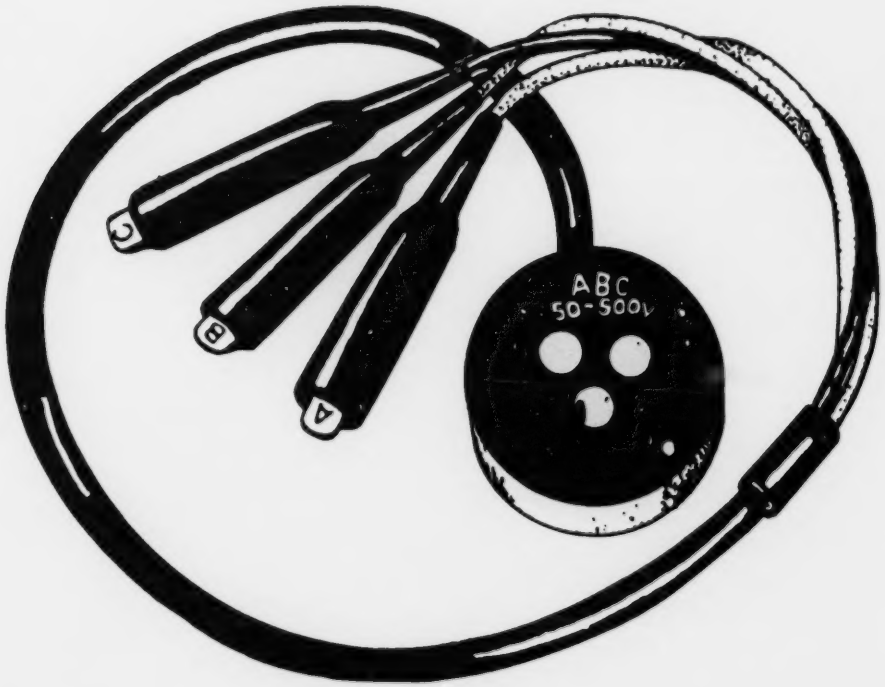
Phase Difference In Electrical Degrees



A. Single-phase B. Two-phase Generator C. Three-phase Generator

May be photocopied for student use.

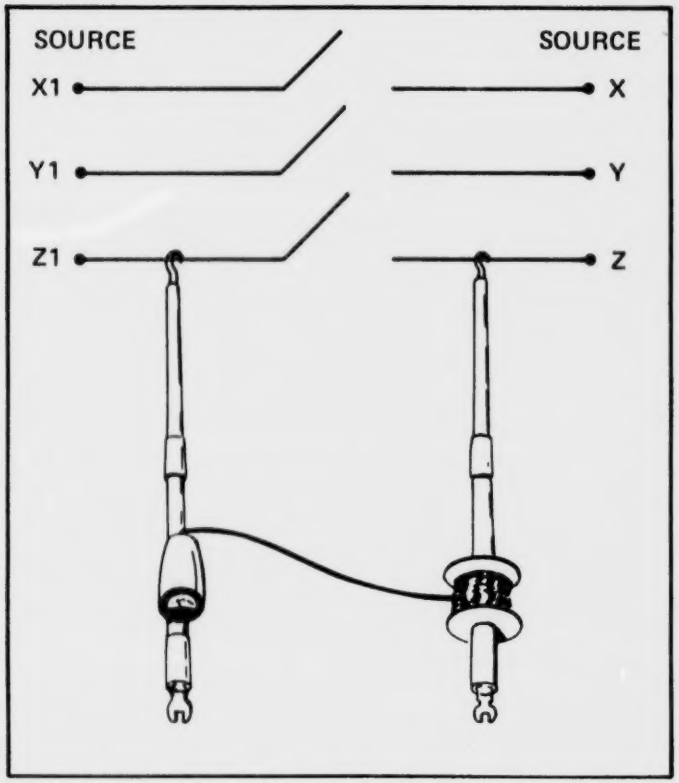
Phase Sequence Indicator

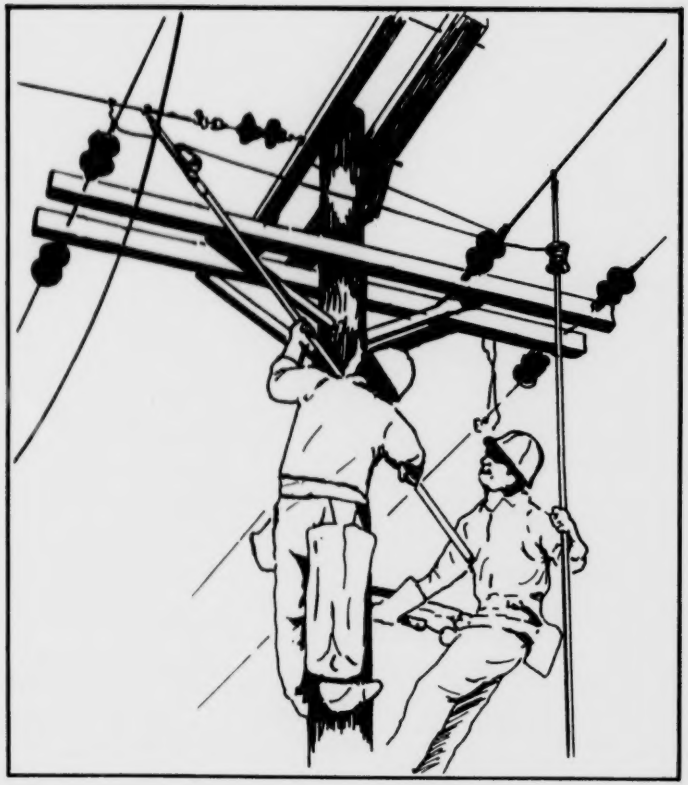


Leads are color-coded red, white, and blue. A small 3-phase motor in the indicator rotates according to the phase sequence

May be photocopied for student use

Phasing Circuits To Be Paralleled





May be photocopied for student use.

PHASING
UNIT 4

TEST

NAME _____ SCORE _____

1. Match the terms commonly associated with phasing on the right to the correct definitions.

_____a.	Order in which the voltages of a three-phase circuit appear	1. Phase balance
_____b.	Map which identifies each phase leaving a substation	2. Phase sequence
_____c.	Identifying a phase by color or number from a phasing map or at a substation	3. Circuit phasing
_____d.	Determining potential difference between circuits of different sources to parallel the circuits	4. Phase rotation
_____e.	Distribution of single-phase loads as evenly as possible on a three-phase circuit	5. Phase identification
_____f.	Similar to phase sequence in a three-phase circuit	6. Phasing map
_____g.	Time in electrical degrees by which one wave leads or lags another	7. Phase angle
_____h.	Relationship of current leaving the secondary of a transformer to the current entering the primary	8. Phase difference

2. List elements of phasing.

a. _____

b. _____

c. _____

May be photocopied for student use.

TEST

3. State methods of determining phase rotation.

   a. _____

   _____

   b. _____

   _____

4. State the procedure for changing the direction of rotation of a three-phase motor.

   _____

   _____

   _____

5. Arrange in order the steps to follow when phasing circuits with a phasing meter. Place a "1" before the first step, a "2" before the second step, and so on.

   _____a. Mark the zero reading phases

   _____b. Move one lead of phasing meter from phase to phase on the same source until there is a zero reading on the meter

   _____c. Connect phasing meter to two phases of different sources

   _____d. Continue check until there is a zero reading between all sets of phases

   _____e. Connect meter to another two phases of different sources

6. Arrange in order the steps to follow to identify distribution phases. Place a "1" before the first step, a "2" before the second step, and so on.

   _____a. Identify the phases as A, B, and C from left to right

   _____b. Identify all circuits in a clockwise direction in sequence with the next circuit to the right as 3A, 3B, and 3C

   _____c. Face the direction of the load

   _____d. Select the circuit which runs north or close to north from a substation

   _____e. Identify the circuit to the right or clockwise direction from the circuit running north as 2A, 2B, and 2C from left to right

7. Evaluated on Assignment Sheet 1.

May be photocopied for student use.

A CIMC "RAINBOW PROGRAM"

FOR STANDARDS OF TEACHING EXCELLENCE

One very important factor contributing to higher student performance is the expectation of parents and teachers. Experience suggests that teachers and parents who expect student success find that students perform better, attend class more regularly, have positive attitudes, and stay in school longer. The students' success and confidence in their ability to learn may cause additional growth and behaviors that exert a positive influence throughout life.

STUDENT'S PROMISE

Let it be publicly known that students in this program have high expectations of achievement.

I recognize that America's future is dependent on my success in school.
I will attend school regularly.
I will keep regular study hours at home.
I will read each day at home.
I will never accept failure.
I will accept responsibility for my school challenges.
I will respect the rights and feelings of others at home, school, and work.
I will develop positive qualities in myself that my friends will admire.
If I have difficulty, I will insist on help with my school work.
If I have difficulty, I will always try harder.
I will ask my teacher for clear learning objectives.
I will practice good citizenship skills at home, school, and work.
I will keep my parents/guardians informed daily about my school activities.
I will develop goals for school, home, and work.
I will seek advice from my teachers, parents/guardians, and counselors on career guidance.
I will constantly practice the skills of a good student.

CIMC

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Power Line Technician

Second Edition

Module E

- Meters and Meter Application
- System Knowledge
- Transformer Connections and Banking
- Phasing

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Student Workbook

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TI3019

Power Line Technician: Module E

Student Workbook

Developed by the
Curriculum and Instructional Materials Center
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97-012244

TI3019

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2. Introduction to Power Line Technician's Training
3. Job Advancement
4. General Safety

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2. Communications
3. Basic Electrical Theory
4. Rope and Rigging
5. Overhead Construction
6. Underground Distribution Construction
7. Personal Climbing Tools and Equipment
8. Right-of-Way
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2. Conductors
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4. Generators and Batteries
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METERS AND METER APPLICATION
UNIT 1

UNIT OBJECTIVE

After completion of this unit, the student should be able to match terms and symbols used with metering to the correct meanings. The student should be able to select meters for various applications and be able to calculate multipliers for meters. This knowledge will be evidenced through demonstration and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms commonly associated with metering to the correct definitions.
2. List general types of meters.
3. List types of meters by base construction.
4. List classes of meters and the current-carrying capacity of each.
5. Match meters to types of service.
6. Match meter voltage ratings to types of service.
7. Match abbreviations and symbols used with metering circuit diagrams to the correct meanings.
8. List uses of current transformer metering.
9. List uses of self-contained meters.
10. Identify various self-contained meter connections.
11. Identify various transformer-rated meter connections.
12. Identify various transformer-rated meter connections for 600 volts or above.
13. State the procedure for selecting the correct meter.
14. List methods for determining voltage for wye and delta connected meters.
15. Match types of services to specific uses.
16. List types of meters which have multipliers.
17. Arrange in order the correct procedure for determining meter multipliers.

OBJECTIVE SHEET

18. List precautions to observe with metering.

19. Calculate the multiplier for a transformer-rated meter connected to a secondary line. (Assignment Sheet 1)

20. Calculate the multiplier for a transformer-rated meter connected to a primary line. (Assignment Sheet 2)

METERS AND METER APPLICATION
UNIT 1

INFORMATION SHEET

1. Match terms commonly associated with metering to the correct definitions.

   - Power — Rate at which an electrical circuit performs work
   - Energy — Power multiplied by time

     Example: Power in a circuit = 5 kW
     Amount of time power is used = 2 hours
     2 x 5 = 10 Kilowatt-hours

   - Watt-hour meter — Instrument which measures electrical energy
   - Register — Gear train arranged to count the revolutions of a meter disc (Transparency 1)
   - Watt-hour — One watt for one hour
   - Kilowatt-hour — One thousand watts for one hour
   - Stator — Stationary part of a meter which produces a magnetic flux that causes the meter disc to turn (Transparency 2)
   - Damping system — Magnet or magnets which cause a retarding force on the meter disc
   - Demand — Power requirements (kW) over a period of time, usually 15 or 30 minutes
   - Detent — Device installed on a meter to prevent the meter from running backwards when current flow through the meter is reversed
   - Uni-directional register — Meter register which registers energy even if meter is installed upside down
   - Potential indicator — Small lamp that indicates the presence of voltage on the potential coil
   - Polyphase meter — Combination of single-phase meter stators in a single unit (Transparency 3)
   - Class — Maximum current-carrying capability of a meter
   - Self-contained meter — Meter which carries entire load of current through its current coils

INFORMATION SHEET

- Transformer-rated meter — Meter that is used with current transformers to measure electrical energy
- K_h (meter constant) — Watt-hours per revolution of the meter disc
- R_r (register ratio) — Ratio of revolutions of the first register shaft to each revolution of the first pointer shaft (Transparency 4)
- First reduction — Ratio of revolutions of the meter disc to one revolution of the first register shaft (Transparency 1)
- Current transformer ratio — Relationship of current flow through a current transformer to the output current

  Example: Current transformer rating 200 to 5
  Ratio = Current capacity divided by output current
  $\frac{200}{5}$ = 40 to 1 ratio

  (NOTE: A current flow through a 200 to 5 current transformer of 40 amperes will induce one ampere of output current which flows through and is registered by the Kilowatt-hour meter. The meter reading would be multiplied by 40 to get the correct amount of energy used.)

2. List general types of meters.
   - Digital meters (Transparency 5)
   - Self-contained
   - Transformer-rated
3. List types of meters by base construction.
   - Socket base ("S" base)
   - Bottom connected ("A" base)
4. List classes of meters and the current-carrying capacity of each.
   - Class 10 — Maximum current of 10 amperes
   - Class 20 — Maximum current of 20 amperes
   - Class 100 — Maximum current of 100 amperes
   - Class 200 — Maximum current of 200 amperes

INFORMATION SHEET

5. Match meters to types of service.

   - Single-phase two-wire service — Use two-wire meter
   - Single-phase three-wire service — Use three-wire meter
   - Three-phase three-wire delta service — Use three-wire delta meter
   - Three-phase four-wire delta service — Use four-wire delta meter
   - Three-phase four-wire wye service — Use four-wire wye meter

   (NOTE: The amperage or class of meter to be used is determined by the size of the transformer and service and the consumer's load requirements. The meter should be large enough to carry the heaviest load the consumer will have.)

6. Match meter voltage ratings to types of service.

   - Single-phase two-wire service — Voltage rating is the same as phase-to-ground voltage of service

     Example: 120-volt two-wire service uses 120-volt two-wire meter

   - Single-phase three-wire service — Voltage rating is the same as phase-to-phase voltage

     Example: 120/240-volt three-wire service uses 240-volt three-wire meter

   - Three-phase three-wire delta service — Voltage rating is phase-to-phase voltage of service

     Example: 480-volt three-wire three-phase service uses 480-volt three-wire three-phase meter

   - Three-phase four-wire delta service — Voltage rating is the same as phase-to phase voltage

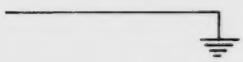
     Example: 120/240-volt four-wire service uses 240-volt four-wire meter

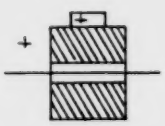
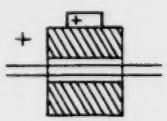
   - Three-phase four-wire wye service — Voltage rating is the same as phase-to ground voltage

     Examples: 120/208-volt four-wire service uses 120-volt four-wire wye meter; 277/480-volt four-wire wye service uses 240-volt four-wire wye meter

INFORMATION SHEET

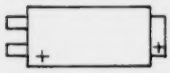
7. Match abbreviations and symbols used with metering circuit diagrams to the correct meanings.

- No connection
- Solid connection
- Ground 
- Potential transformer **PT**

  (NOTE: This is the abbreviation.)
- Current transformer **CT**
- Current connection C_1
- Potential connection P_1
- Ground connection **G**
- Neutral connection **N**
- Self-contained **SC**
- Transformer-rated **TR**
- Two-wire current transformer 
- Three-wire current transformer 

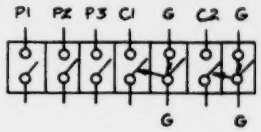
INFORMATION SHEET

- Potential transformer

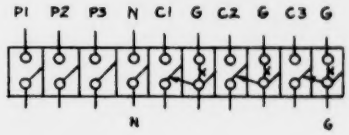


(NOTE: The polarity marks on current and potential transformers vary in type. The marks may be white dots or other markings.)

- Seven pole test block



- Ten pole test block



- Delta connected △

- Wye connected **Y**

8. List uses of current transformer metering.

   - Loads greater than 200 amperes
   - Voltages of 480 or higher
   - Locations where it would be impractical to install a large metering conductor

9. List uses of self-contained meters.

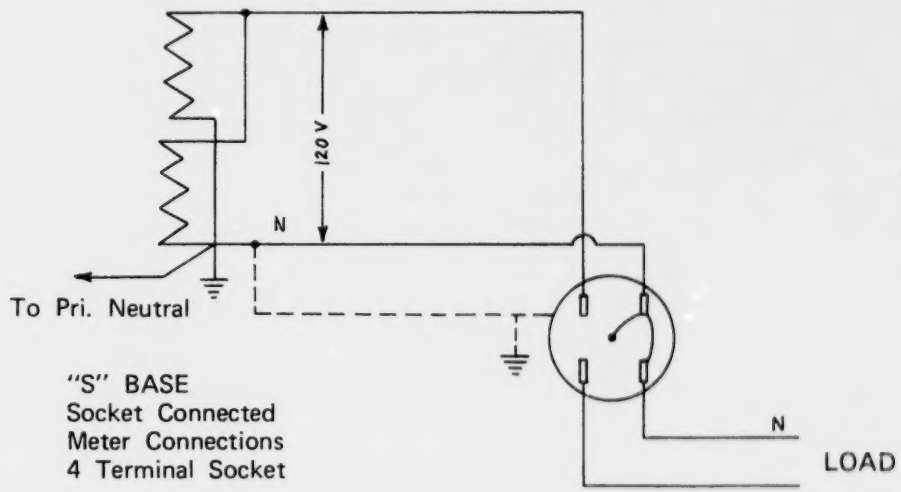
   - Loads of 200 amperes or less
   - Voltages of 480 volts or less

   (NOTE: It is recommended that current transformer metering be used on 480-volt services; however, 480-volt self-contained meters are used on small 480-volt loads.)

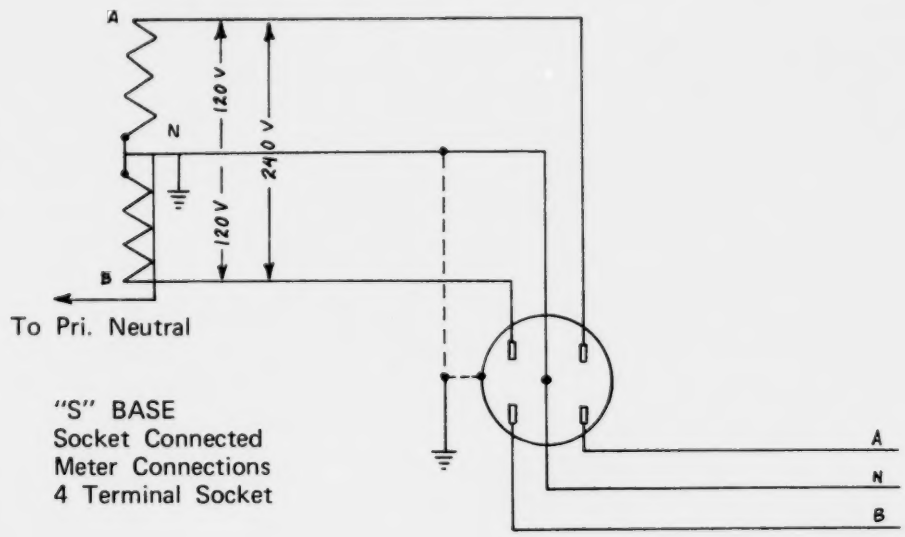
INFORMATION SHEET

10. Identify various self-contained meter connections.

- Two-wire single-phase 120-volt service

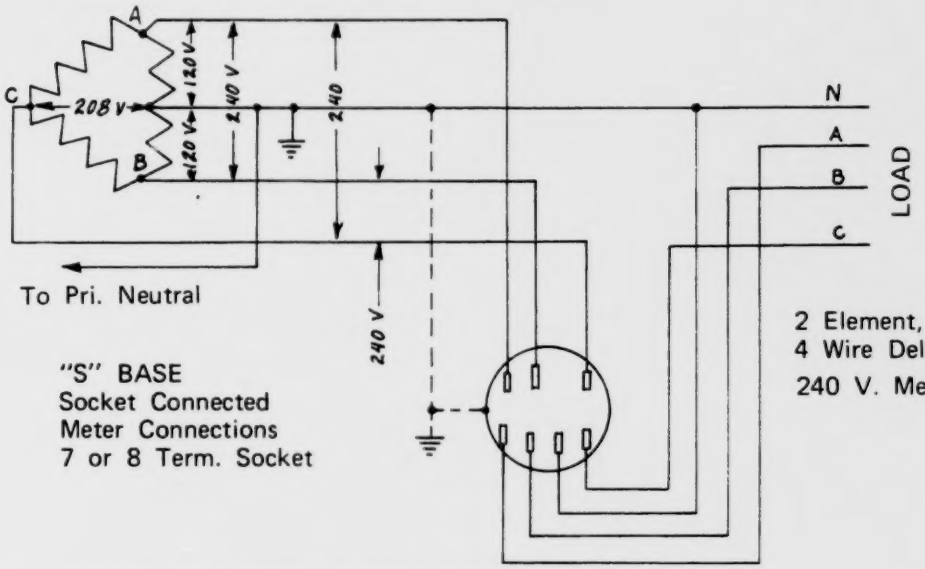


- Three-wire single-phase 120/240-volt service

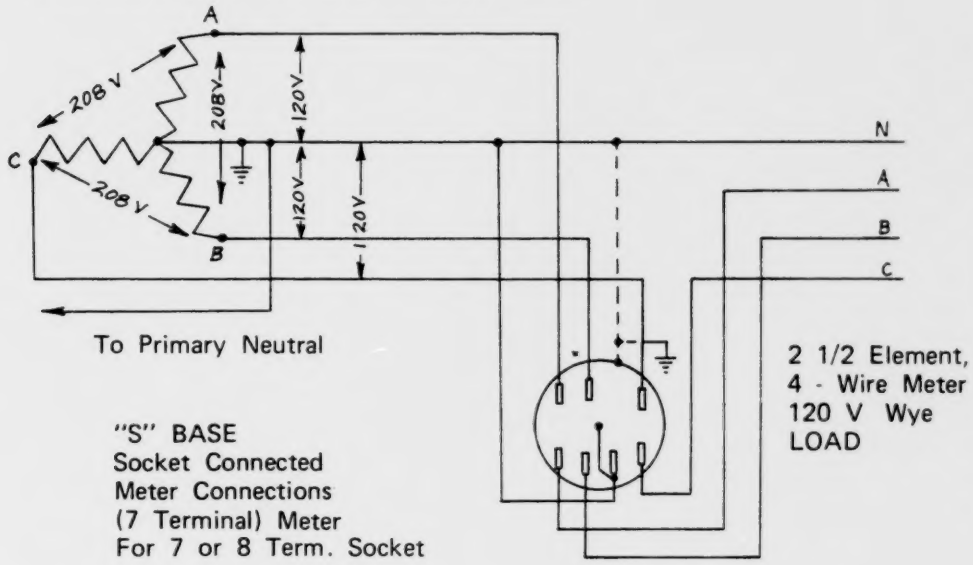


INFORMATION SHEET

- Four-wire three-phase 120/240-volt delta service

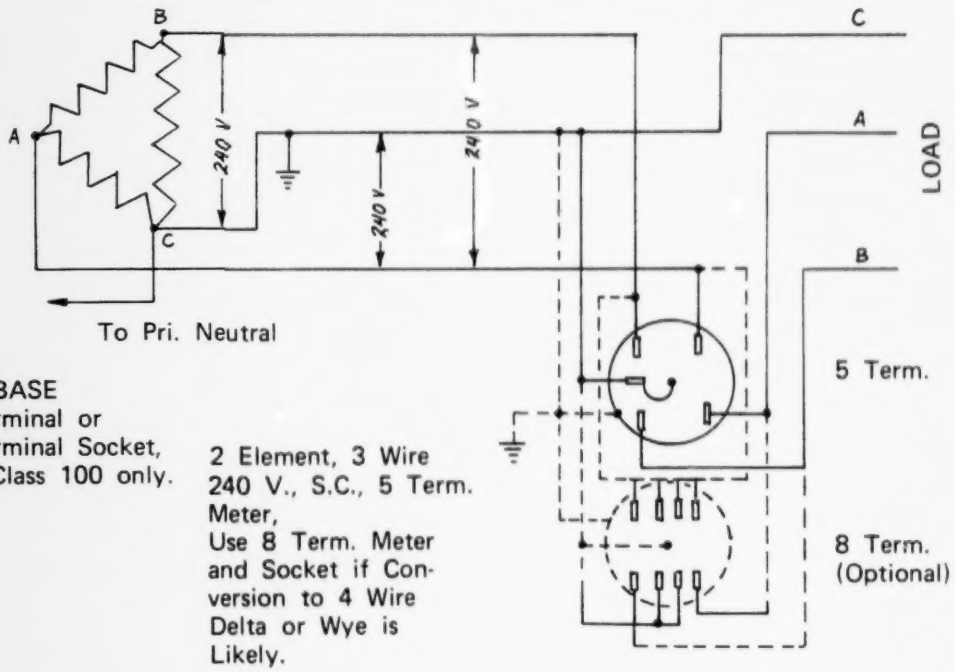


- Four-wire three-phase 120/208-volt wye service



INFORMATION SHEET

- Three-wire three-phase 240-volt corner ground delta service



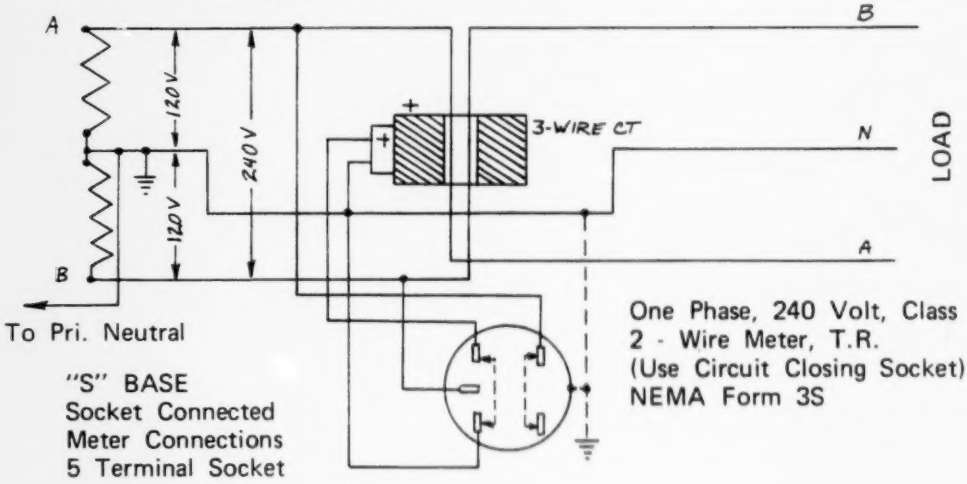
"S" BASE
5 Terminal or
8 Terminal Socket,
For Class 100 only.

2 Element, 3 Wire
240 V., S.C., 5 Term.
Meter,
Use 8 Term. Meter
and Socket if Conversion to 4 Wire
Delta or Wye is
Likely.

(NOTE: This metering method is also used with 480-volt three-wire service.)

11. Identify various transformer-rated meter connections.

- Three-wire single-phase 120/240-volt service

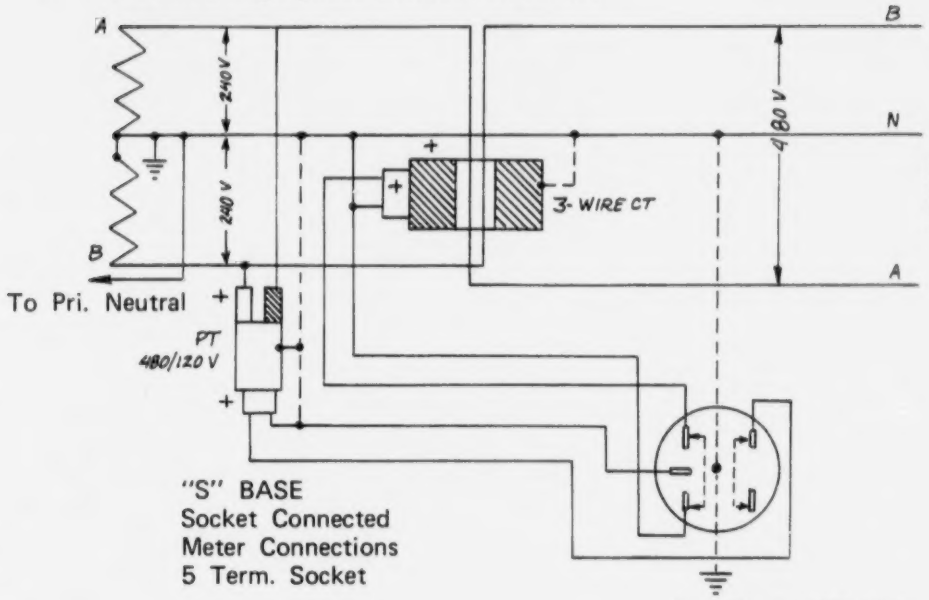


"S" BASE
Socket Connected
Meter Connections
5 Terminal Socket

One Phase, 240 Volt, Class 10
2 - Wire Meter, T.R.
(Use Circuit Closing Socket)
NEMA Form 3S

INFORMATION SHEET

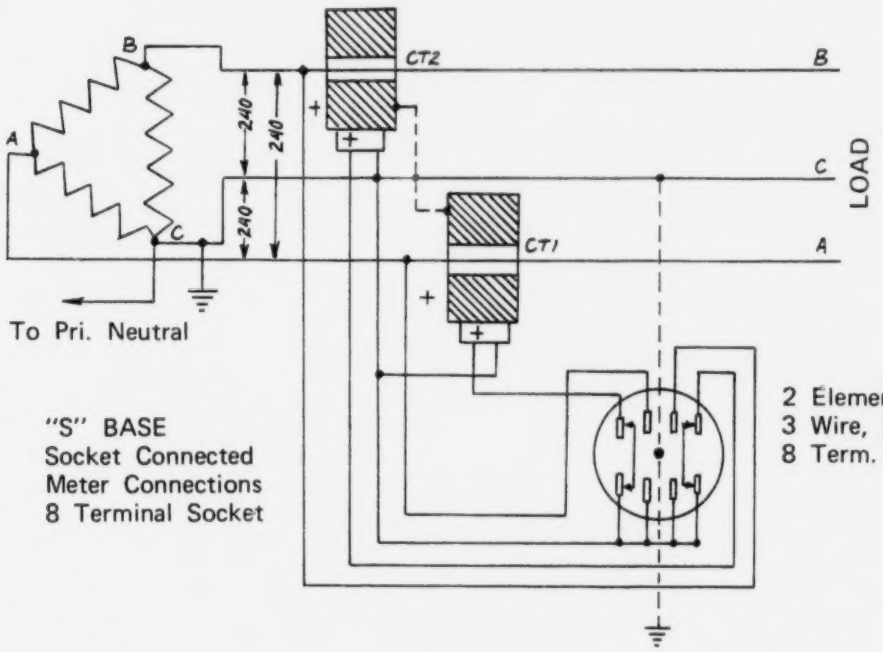
- Three-wire single-phase 240/480-volt service



"S" BASE
Socket Connected
Meter Connections
5 Term. Socket

1 - Phase, 120 Volt, T.R.
Class 10, 2 - Wire Meter
(Use Circuit Closing Socket)

- Three-wire three-phase 240-volt delta service

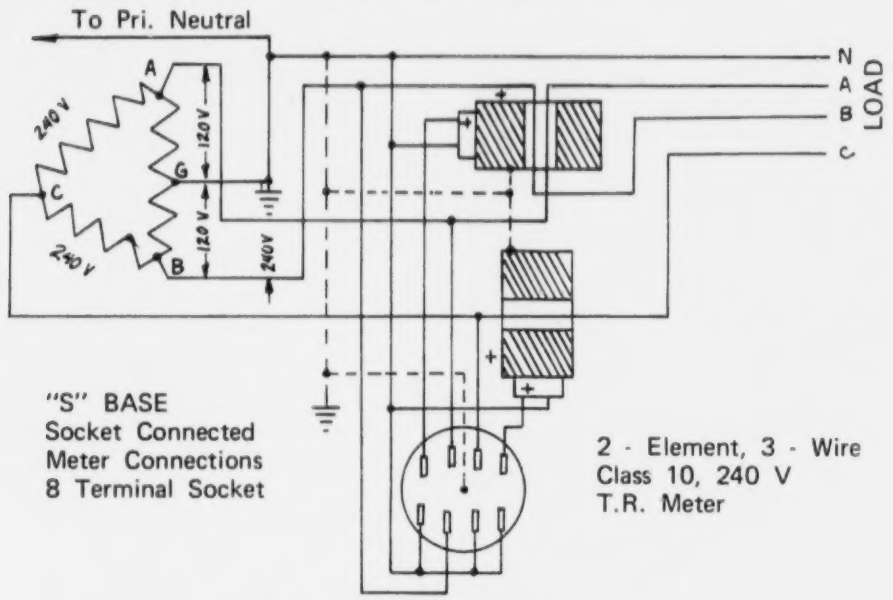


"S" BASE
Socket Connected
Meter Connections
8 Terminal Socket

2 Element
3 Wire, 240 V., T.R.
8 Term. Meter

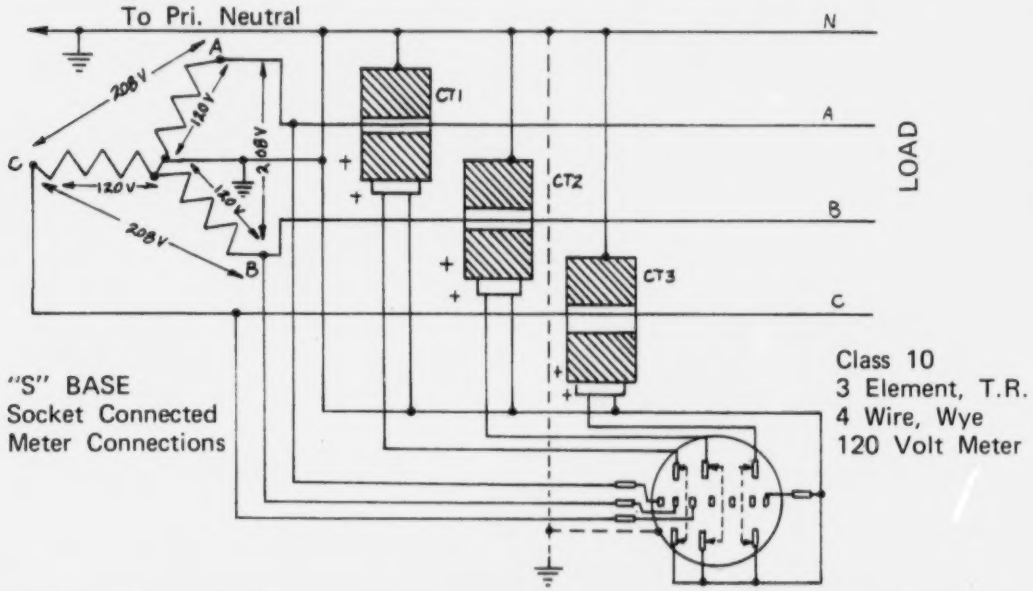
INFORMATION SHEET

- Four-wire three-phase 120/240-volt delta service



- Four-wire three-phase 120/208-volt wye service

(NOTE: This connection is also used with a 277/480-volt service by using a 240-volt meter.)

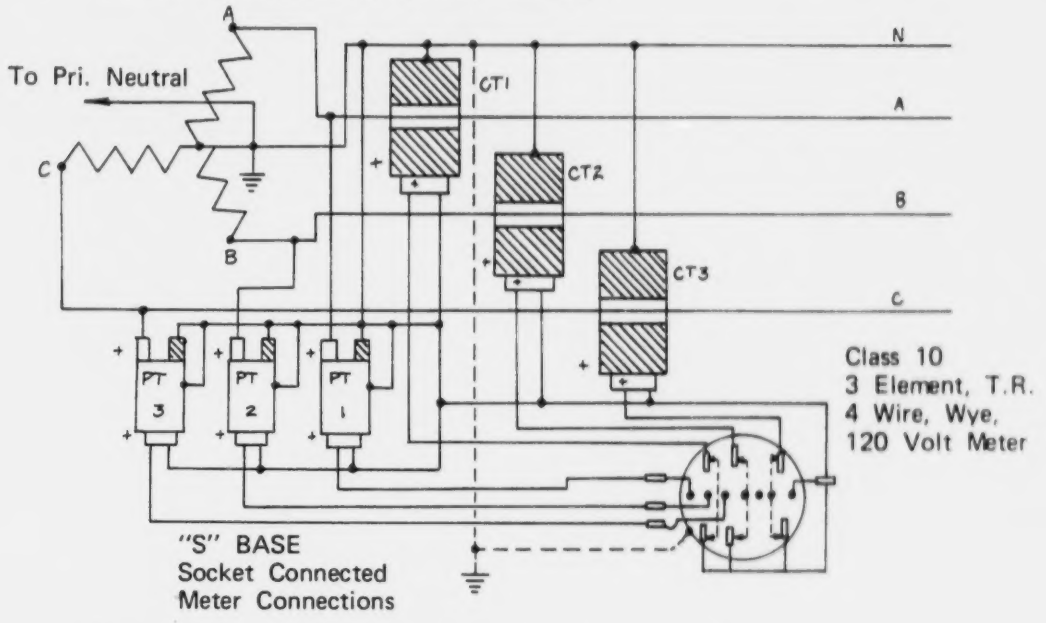


(NOTE: All of the metering connections shown may be installed with a bottom connected "A" base meter. Whichever method is used, the wiring diagrams must be followed precisely to avoid costly errors in the meter registration.)

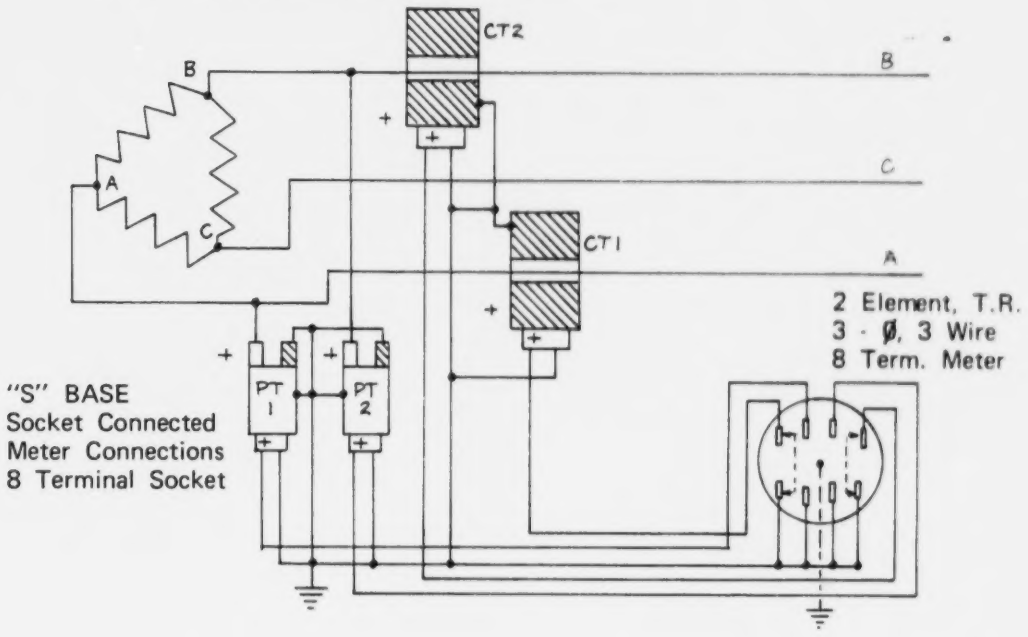
INFORMATION SHEET

12. Identify various transformer-rated meter connections for 600 volts or above.

- Four-wire three-phase wye primary metering



- Three-wire three-phase delta primary metering



INFORMATION SHEET

13. State the procedure for selecting the correct meter.

- Determine class of meter needed
- Determine voltage to be metered
- Determine phase of meter

  Example: Single or three

- Determine service connection

  Example: Wye or delta

- Determine wires of meter

  Examples: 2, 3, 4

14. List methods for determining voltage for wye and delta connected meters.

- Wye-connected service — Meter voltage will be line-to-ground voltage of service
- Delta-connected service — Meter voltage will be line-to-line voltage of service

(NOTE: An exception to the methods listed is the meter for 277/480-volt wye-connected service. Even though the line-to-ground voltage is 277 volts, the meter voltage for this application is 240 volts.)

15. Match types of services to specific uses.

- Two-wire single-phase 120-volt service — Billboards, shallow well pumps, and small dwellings
- Three-wire single-phase 120/240-volt service — Most residences and small industrial locations
- Four-wire three-phase 120/240-volt delta service — Residences where three-phase power is needed for heating or air conditioning and industrial locations where small three-phase power is needed with large light loads
- Three-wire three-phase 240 or 480 volt delta service — Power loads only for oil field and irrigation pumps
- Four-wire three-phase 120/208-volt wye service — Apartment complexes where both light and power loads may be heavy
- Four-wire three-phase 277/480-volt wye service — Commercial and industrial areas where long circuit distances can be made with small conductor

INFORMATION SHEET

16. List types of meters which have multipliers.

- All transformer-rated meters
- Some self-contained meters used on heavy loads

17. Arrange in order the correct procedure for determining meter multipliers.

- Record information from meter nameplate and meter register, K_h and R,
- Record ratios from current transformer and potential transformer
- Record first gear reduction given by meter manufacturer
- Multiply meter constant x register ratio x CT ratio x PT ratio x first gear reduction and divide product by 10,000

  Example:

  Meter Kh = 1.8
  Meter Rr = 55 5/9
  CT ratio = 50:5
  PT ratio = 60:1
  First gear reduction = 100:1

  $18/10 \times 500/9 \times 50/5 \times 60/1 \times 100/1 = \frac{6{,}000{,}000}{10{,}000} = 600$

  Meter multiplier = 600

  (NOTE: The multiplier for a secondary-rated meter may be calculated by multiplying 1 x CT ratio if the meter has not had any parts changed. It is better to figure the multiplier on all transformer-rated meters using all components to avoid errors in the calculation.)

18. List precautions to observe with metering.

- Wear eye protection
- Wear your rubber gloves
- Do not remove a meter which is under load
- Short circuit the secondary side of current transformers before removing the meter

  (NOTE: An open secondary circuit connected to a current transformer on an energized conductor can develop high voltage which is dangerous to personnel and equipment.)

METERS AND METER APPLICATION
UNIT 1

ASSIGNMENT SHEET 1

OBJECTIVE 19 — CALCULATE THE MULTIPLIER FOR A TRANSFORMER-RATED METER CONNECTED TO A SECONDARY LINE.

Use the following information from meter nameplate and register and use 400:5 current transformer ratio.

R_r = 55 5/9

K_h = 1.8

G_r = 100:1

CT ratio = 400:5

Multiply $R_r \times K_h \times G_r \times CT_r$ and divide by 10,000

METERS AND METER APPLICATION
UNIT 1

ASSIGNMENT SHEET 2

OBJECTIVE 20 — CALCULATE THE MULTIPLIER FOR A TRANSFORMER-RATED METER CONNECTED TO A PRIMARY LINE.

Use the following information from meter nameplate and register and use 25:5 current transformer ratio and use 60:1 potential transformer ratio.

R_r = 166 2/3

K_h = 1.8

G_r = 50:1

CT ratio = 10:5

PT ratio = 60:1

Multiply $R_r \times K_h \times G_r \times CT_r \times PT_r$ and divide by 10,000

SYSTEM KNOWLEDGE
UNIT 2

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify symbols used to represent overhead and underground lines and equipment and cultural features. The student should be able to use precautions with automated equipment. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms used with system knowledge to the correct definitions.
2. Define symbols used with overhead lines and equipment identification on system maps.
3. Define symbols used with underground lines and equipment identification on system maps.
4. Identify symbols used to locate cultural features on system maps.
5. List functions of automated equipment.
6. List precautions to observe with automated equipment.
7. Select from a list conditions associated with system terrain.
8. Identify symbols on a system map. (Assignment Sheet 1)

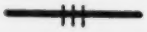
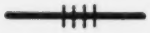
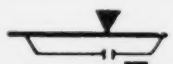
SYSTEM KNOWLEDGE
UNIT 2

INFORMATION SHEET

1. Match terms used with system knowledge to the correct definitions.

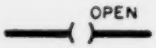
   - Capacitor station — Location where one or more line voltage capacitors are installed
   - Automated equipment — Equipment that operates switches on capacitor, primary line, and other equipment without manual assistance
   - Fault current — Current that flows through a conductor when a fault occurs on a circuit line
   - Galvanic action — Corrosion of anchor rods and other underground equipment caused by the flow of direct current to the neutral conductor and returning to earth through the underground equipment (Transparency 1)
   - Feeder capacity — Ampacity of the conductors that distribute power from a substation
   - Multi-feed bank — Transformer bank which is energized by phases which have sources in different directions or possibly fed from different substations
   - Phase transposition — Location in the primary or transmission line where the phases change positions (Transparency 2)

2. Define symbols used with overhead lines and equipment identification on system maps.

   - 1Ø primary line
   - VØ primary line 
   - 3Ø primary line 
   - Transformer
   - Primary, secondary underbuild 
   - Secondary construction (base)
   - Transformer bank 3Ø△, rating KVA (system-owned)
   - Transformer bank 3Ø△, rating KVA (consumer-owned)
   - Transformer bank 3ØY, rating KVA (system-owned)
   - Transformer bank 3ØY, rating KVA (consumer-owned)

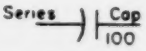
PLT E - 2 - 4

INFORMATION SHEET

- Transformer bank 3Ø (open Δ)
- Transformer bank 3Ø (open Y)
- Normally open point 

- Fused cut-out, rating (single shot)
- Fused cut-out, rating (2 shot)
- Fused cut-out, rating (3 shot)
- Automatic circuit recloser, rating
- Automatic line sectionalizer, rating
- Voltage regulator, rating, KVA
- Minimum and maximum fault current
- Air break switch (ganged)

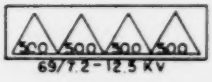
- Disconnect switch

- Capacitor bank-series, rating 

- Capacitor bank-shunt, rating
- Capacitor bank-shunt, switched

Indicate delta or wye when 3-phase bank

- Metering point, capacity 500 KVA

- Substation (indicate voltage and transformer size) 

- Substation, 3-phase transformer (indicate voltage, transformer size, and winding)

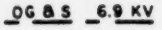
- Oil circuit breaker (station type)

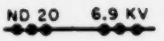
- Generating plant capacity 22000 KW

(NOTE: Use **S** for steam, **H** for hydro, **IC** for internal combustion, **N** for nuclear, and **GT** for gas turbine.)

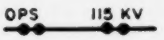
- Distribution line (existing)

INFORMATION SHEET

- Other distribution line, voltage in kV, and name of utility 

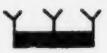
- Transmission line, existing voltage, and system designation 

- Transmission line, proposed

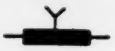
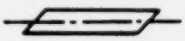
- Transmission line, voltage, and name (other utilities) 

- Consumer receiving electrical service

3. Define symbols used with underground lines and equipment identification on system maps.

- Transformer, underground
- Pedestal, above ground or surface mounted
- Pedestal, underground
- Splice (nonseparable)
- T-tap (nonseparable)
- Elbow terminator
- Bushing plug
- Parking stand (insulated)
- Parking stand (grounded)
- UM 3-02 (2 point load break connection
- UM 3-11 (1 point load break, 1 point termination)
- UM 3-03 (3 point load break) 

INFORMATION SHEET

- UM 3-12 (2 point load break, 1 point termination)
- UM 3-21 (1 point load break, 2 point termination) 
- Fault indicator (F)
- Cable in conduit 
- Single-phase primary ——— U ———
- V-phase primary ——— U ——— 2 ———
- Three-phase primary ——— U ——— 3 ———
- Single-phase primary riser
- V-phase primary riser
- Three-phase primary riser
- Secondary or service (3 wire) - - - - U - - - - - - - -
- Secondary or service (4 wire) - - - - U - - - - 4 - - - -
- Transformer, surface mounted □

4. Identify symbols used to locate cultural features on system maps.

- Federal highway (66)
- State road (52)
- County road
- Unimproved road = = = = = = = =
- Railroad (with station)
- Telephone and telegraph line —T——T——T-
- Bridge
- Cities and towns (within corporate limits)
- Towns and villages ○
- State capital ⊛

INFORMATION SHEET

- County seat ◉
- Houses and other buildings ▟ ■
- School ▟

5. List functions of automated equipment.
   - Switches transmission line feed when fault occurs
   - Switches capacitors on and off the line
   - Starts and connects generator to line when outage occurs
   - Connects distribution circuits together during peak loads
6. List precautions to observe with automated equipment.
   - Know the locations of all automated equipment on the system
   - Know the functions of all automated equipment on the system
   - Be able to override or disconnect automated equipment when necessary
7. Select from a list conditions associated with system terrain.
   - Road conditions during wet weather
   - Soil conditions throughout the system
   - Areas where blasting may be required to construct lines
   - Areas of limited access
   - Areas where special equipment may be required to obtain access

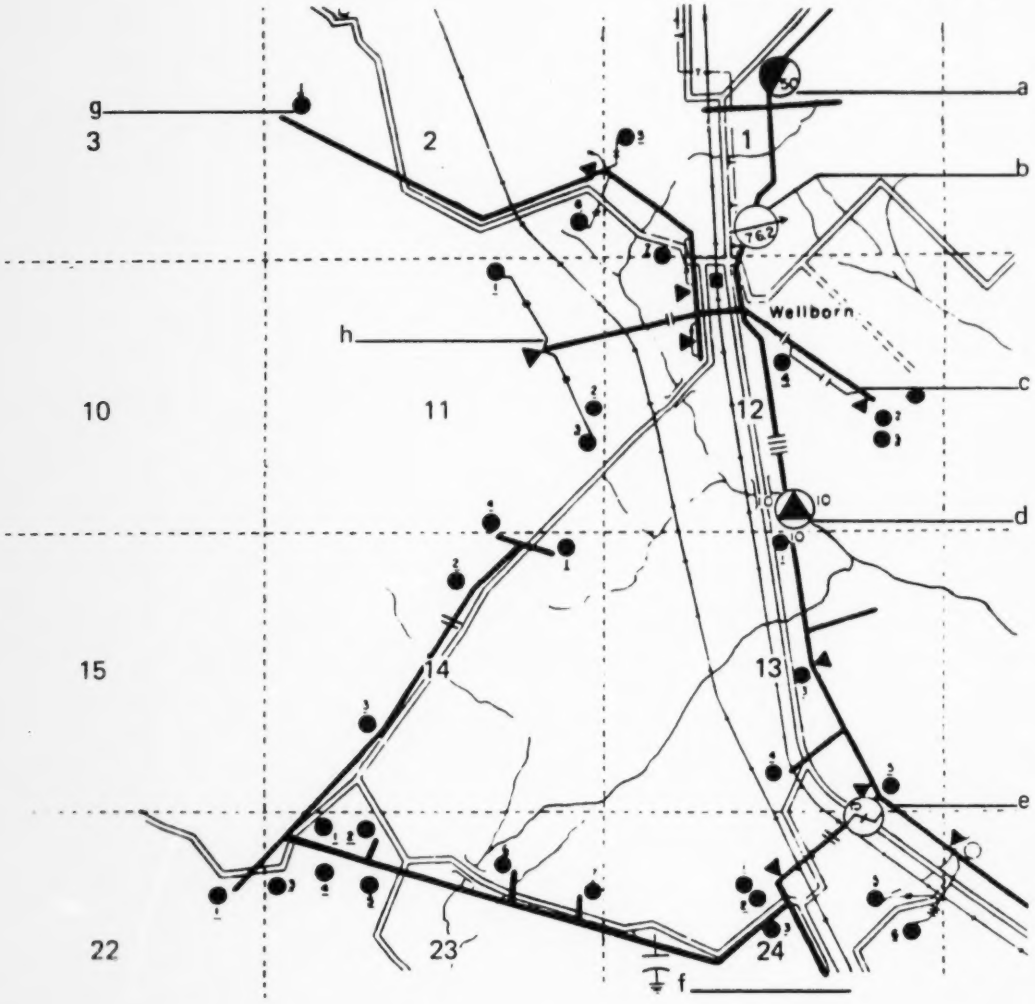
SYSTEM KNOWLEDGE
UNIT 2

ASSIGNMENT SHEET 1

OBJECTIVE 8 — IDENTIFY SYMBOLS ON A SYSTEM MAP.

Identify the symbols on the map by placing the corresponding number in the blank.

1. Three-phase delta bank
2. Voltage regulator
3. Capacitor
4. Primary, secondary underbuild
5. Fuse cut-out
6. Secondary construction
7. Consumer receiving electrical service
8. Automatic circuit recloser



TRANSFORMER CONNECTIONS AND BANKING
UNIT 3

UNIT OBJECTIVE

After completion of this unit, the student should be able to select and connect transformers in two- and three-transformer banks. The student should be able to connect transformer windings in series and parallel and be able to locate a faulted transformer in a bank. This knowledge will be evidenced through demonstration and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms commonly used with transformer connections and banking to the correct definitions.
2. Define characteristics of transformer construction.
3. Match symbols used with transformer voltage rating and connection diagrams to the correct meanings.
4. Discuss transformer polarities.
5. Discuss bushing locations in relationship to polarity on padmount transformers and compare to pole-type in regard to subtractive and additive.
6. Identify secondary coil connections for two- and three-wire service.
7. Identify single-transformer connections for three-wire service.
8. Identify two-transformer banks.
9. Define objectives an electrician must keep in mind when constructing three-phase banks.
10. List in order the step-by-step process for designing three-phase banks.
11. Describe phase relationships between the bushings in three-phase banks.
12. Identify types of primary and secondary connections for three-transformer banks.
13. List precautions to observe when selecting transformers to be banked or paralleled.
14. Identify secondary connections on a four-bushing transformer.

OBJECTIVE SHEET

15. State the correct method of connecting wye and delta transformers to a primary line.

16. Arrange in order the steps to find a faulted transformer in a bank.

17. State the precautions to observe with transformer banks.

18. Connect transformer secondary coils in series and parallel. (Assignment Sheet 1)

19. Connect a wye-delta bank for three-phase four-wire 120/240-volt service. (Assignment Sheet 2)

20. Connect a wye-delta bank for three-phase three-wire 240-volt service. (Assignment Sheet 3)

21. Connect a wye-wye bank for three-phase four-wire 120/208-volt service. (Assignment Sheet 4)

22. Connect an open-wye open-delta bank for three-phase four-wire 120/240-volt service. (Assignment Sheet 5)

23. Connect an open-wye open-delta bank for three-phase three-wire 240-volt service. (Assignment Sheet 6)

24. Connect an open-delta open-delta bank for three-phase four-wire 120/240-volt service. (Assignment Sheet 7)

25. Connect two single-bushing transformers in parallel. (Assignment Sheet 8)

TRANSFORMER CONNECTIONS AND BANKING
UNIT 3

INFORMATION SHEET

1. Match terms commonly used with transformer connections and banking to the correct definitions.

   - Polarity — Designation of relative voltage phase and purely a function of how the leads are brought out of a transformer (Transparency 1)
   - Subtractive polarity — Instantaneous voltages of the two transformer windings subtract from each other when connected in sequence
   - Additive polarity — Instantaneous voltages of the two transformer windings add to each other when connected in sequence
   - Delta — Symbol (Δ) used to identify the diagrams that describe a system using three transformers whose secondary windings are connected in series
   - Star or wye — Symbol (Y) used to identify diagrams that describe a system using three transformers whose secondary windings are paralleled
   - Open delta — Symbol (Λ) used to identify a connection that uses two transformers for a three-phase service
   - Wild leg — Term used to identify the high voltage leg of a four-wire delta-connected secondary
   - Impedance — Combined effect of resistance and inductive reactance
   - GRDY — A winding that can only be used for a phase-to-ground connection

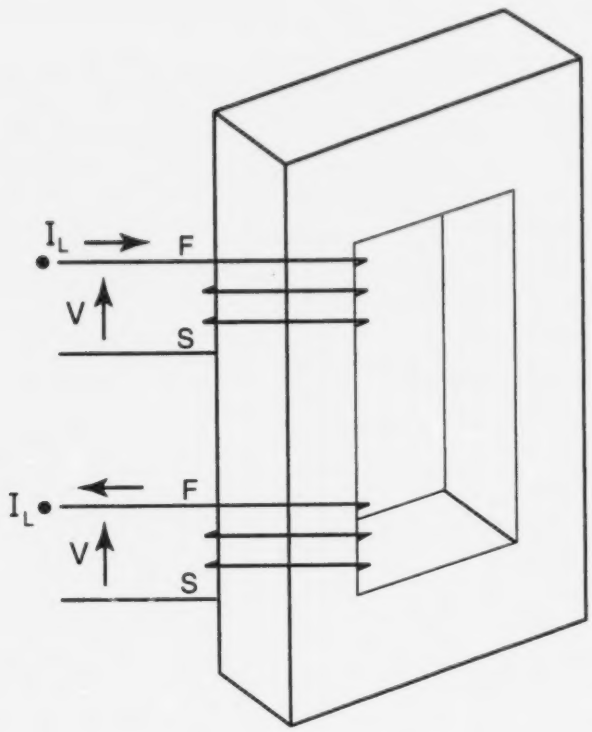
2. Define characteristics of transformer construction. (Transparency 2)

   - When two identical coils are wrapped around an iron core and 60 Hz voltage is applied to one winding, an identical voltage appears on the other winding.
   - When the finish end of each winding is identified with a dot (●), the voltages at the dotted terminals are in phase.
   - When a current is drawn from the second winding, another current must also flow in the first winding, but in the opposite direction.
   - In practical transformers, polarity dots are not used, but corresponding terminals are marked "H1" and "X1" for the primary and secondary terminals whose voltages are in phase.

INFORMATION SHEET

- Distribution transformers do not have identical windings, but the phase relationships between voltages and currents are always as shown below.

  (NOTE: The phase relationship between "H1" and "X1" is very important in the connections and banking of transformers.)



3. Match symbols used with transformer voltage rating and connection diagrams to the correct meanings.

   - — — Separates voltage rating of high side and low side windings
   - / — Separates tap voltage and voltage rating of one winding
   - X — Separates windings that may be connected in parallel or series
   - Y — Indicates a winding suitable for phase-to-ground connection
   - H_1, H_2, and H_3 — Indicate high voltage connections
   - X_1, X_2, X_3, and X_4 — Indicate low voltage connections

INFORMATION SHEET

- H_0 — Indicates the primary ground or common connection
- X_0 — Indicates the secondary ground connection

(NOTE: H_0 and X_0 may not be grounded for certain connections. Also, X_0 is usually going to be grounded external to the transformer.)

4. Discuss transformer polarities. (Transparency 3)

   - Different polarity standards are used, depending on the kVA and primary voltage.

     (NOTE: The use of different polarity standards may have begun as an attempt to limit the voltage between adjacent bushings on the transformer or between the grounded core and the various windings inside the transformer.)

   - Polarity makes no difference to the internal construction of a modern transformer, only to the location of the secondary bushings.

     (NOTE: For pole-type transformers, the physical locations of the bushings correspond to the schematic arrangement on the nameplate.)

   - The bushings may not be located as shown on the nameplate on transformers other than pole-types, such as padmounts, vault-types, etc.

     (NOTE: Phasing can only be determined from the marking of "H1" and "X1".)

5. Discuss bushing locations in relationship to polarity on padmount transformers and compare to pole-type in regard to subtractive and additive. (Transparency 4)

   - The polarity of padmounts is determined <u>strictly</u> from the location of the LV or secondary bushings. When facing the LV compartment, if the left-most bushing is marked "X1," then the polarity is subtractive. Otherwise, it is additive.

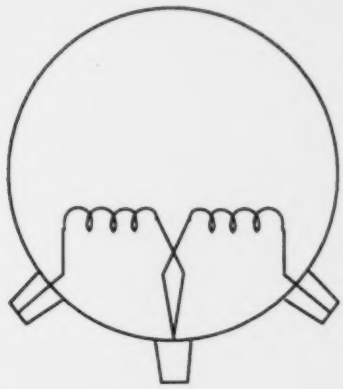
     (NOTE: The rule is stated this way because the "X1" bushing may not be the right-most on an "additive" transformer.)

   - Because the location of "H1" is arbitrary, polarity is completely defined by the relative positions of the LV bushings:

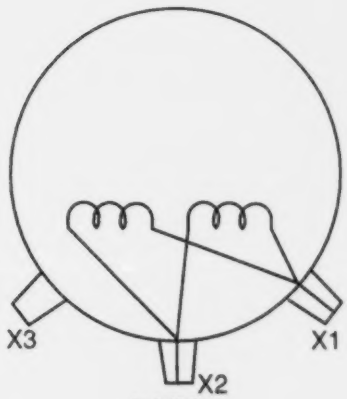
INFORMATION SHEET

6. Identify secondary coil connections for two- and three-wire service.

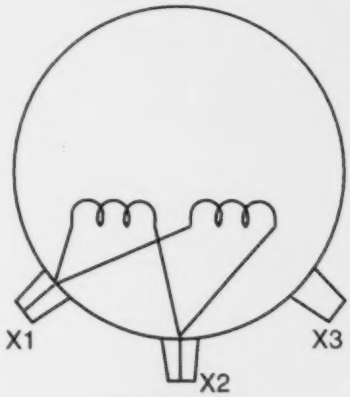
- Series connected for 120/240-volt three-wire service



- Parallel connected for 120-volt two-wire service



Additive Polarity

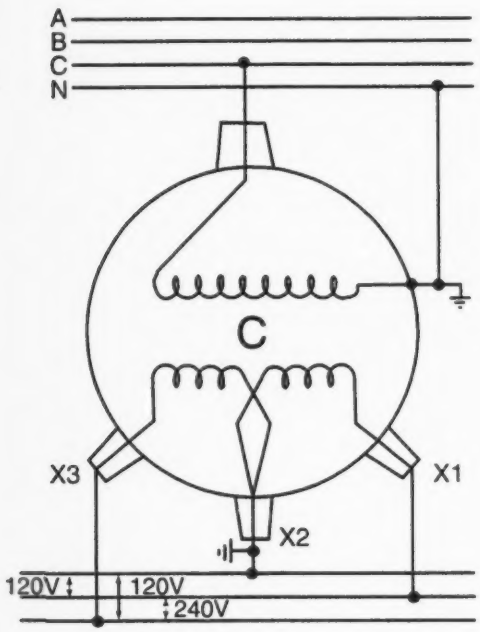


Subtractive Polarity

INFORMATION SHEET

7. Identify single-transformer connections for three-wire service.

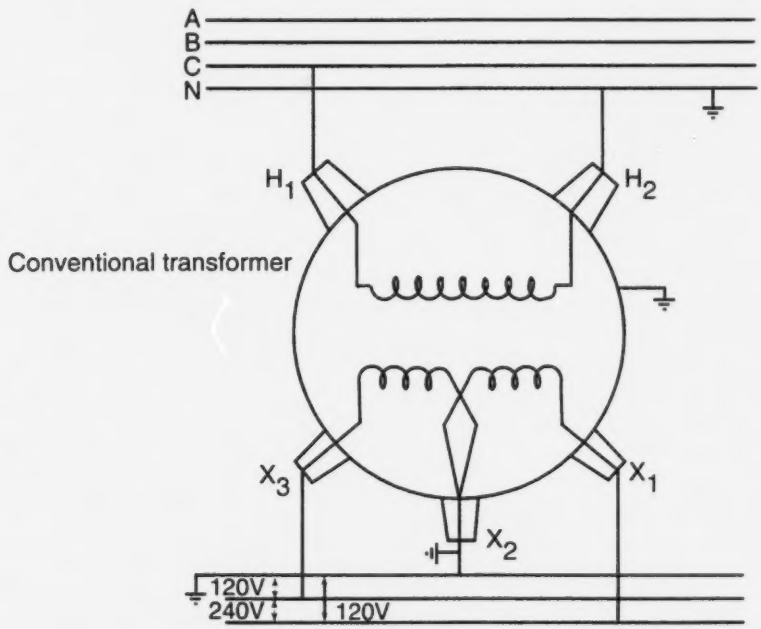
   - Single-bushing primary connection (three-wire 120/240-volt secondary)



(NOTE: A transformer with 1 HV bushing is not necessarily a completely protected transformer!)

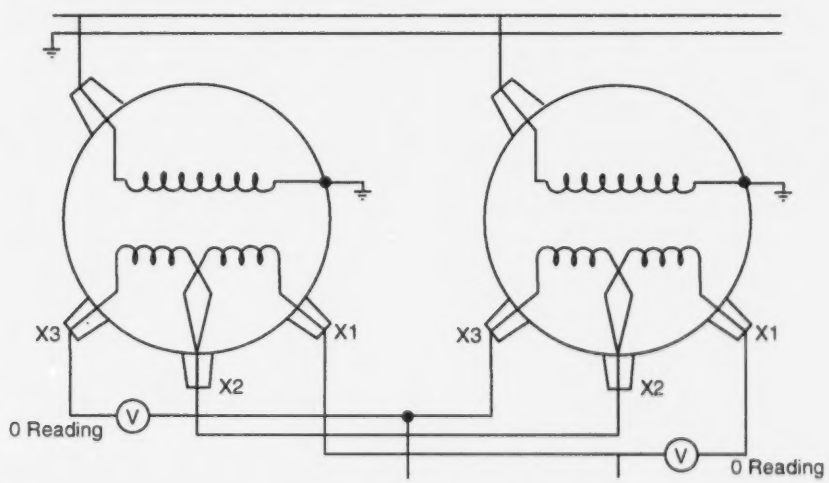
INFORMATION SHEET

- Two-bushing primary connection (three-wire 120/240-volt service)



(NOTE: The secondary coils of both the single- and two-bushing transformers may be connected in parallel for a two-wire service. This may be used for 120/240, 240/480, 240, or 480 volt secondary.)

- Two single-bushing transformers paralleled (three-wire 120/240-volt service)

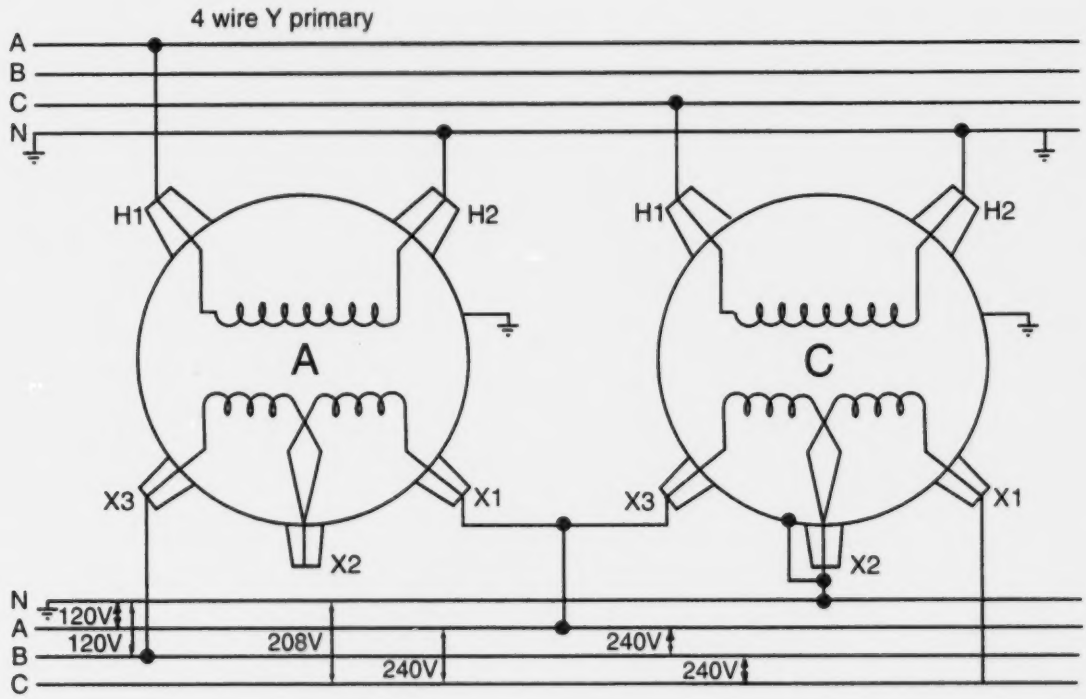


(NOTE: A zero voltage reading will be indicated by checking between the X3 and X1 terminals of each transformer if they have been matched for paralleling.)

INFORMATION SHEET

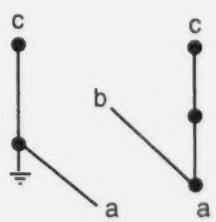
8. Identify two-transformer banks.

- Open-wye open-delta for three-phase four-wire 120/240-volt service



(CAUTION: Only one X_2 bushing may be grounded.)

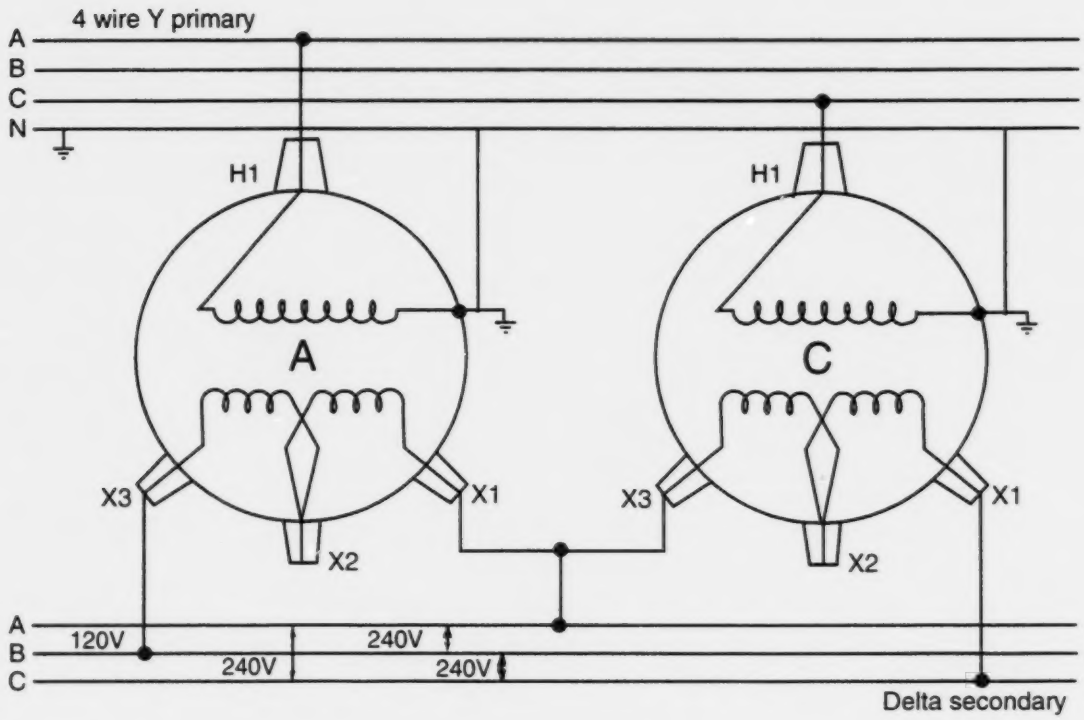
(NOTE: The efficiency of this bank is 86.6% of the rating of the two transformers and is not recommended for large three-phase loads. If both transformers were 50 kVA rated, the actual capacity of the bank would be 86.6 kVA rather than 100 kVA.)



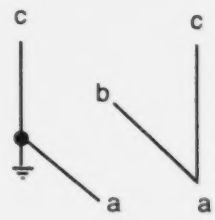
(NOTE: Connection is usually more efficient when lighting load is on the *leading* phase of the two. *Placing* the lighting unit on the right allows a short jumper to LV phase a.)

INFORMATION SHEET

- Open-wye open-delta for three-phase three-wire 240-volt service



(NOTE: If a ground is required, either X_1 or X_2 may be grounded. A ground on X_2 would make this a four-wire 120/240 volt secondary. A ground on X_1 would make this bank a three-wire corner grounded delta secondary. Completely protected or conventional transformers may be used with this bank.)

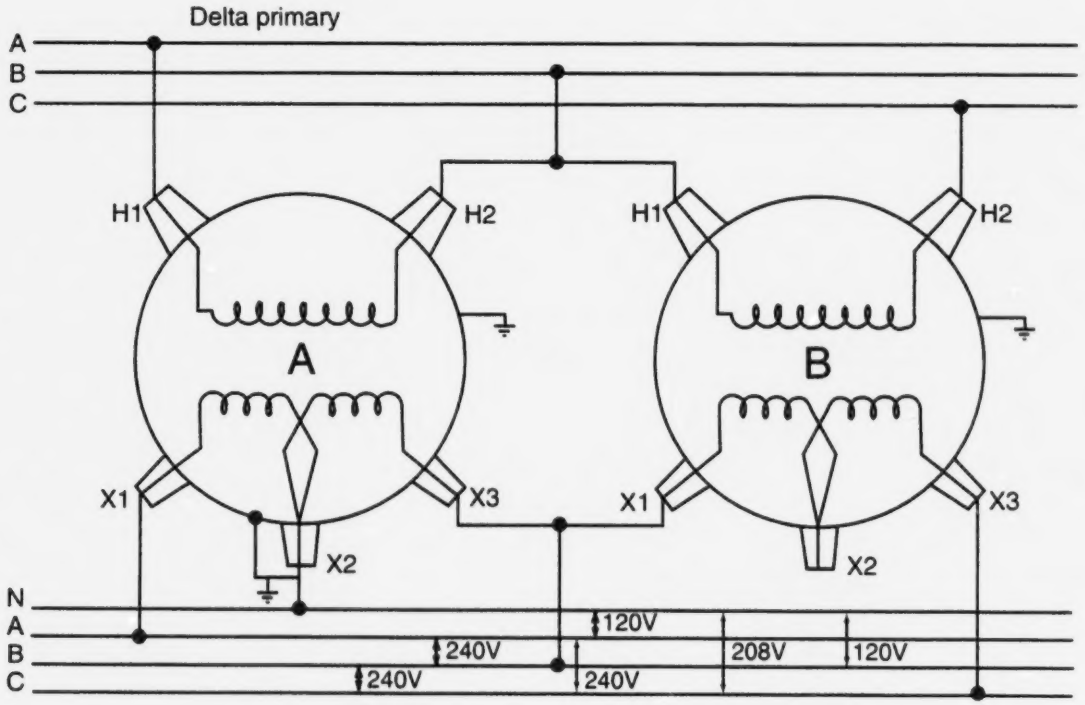


(NOTE: For ease in making the secondary *bus* jumper between X1-X3 to phase A for additive polarity, the leading phase (C) should be on the right.)

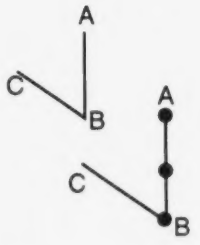
INFORMATION SHEET

- Open-delta open-delta for three-phase four-wire 120/240-volt service

(NOTE: Transformers below are subtractive polarity.)



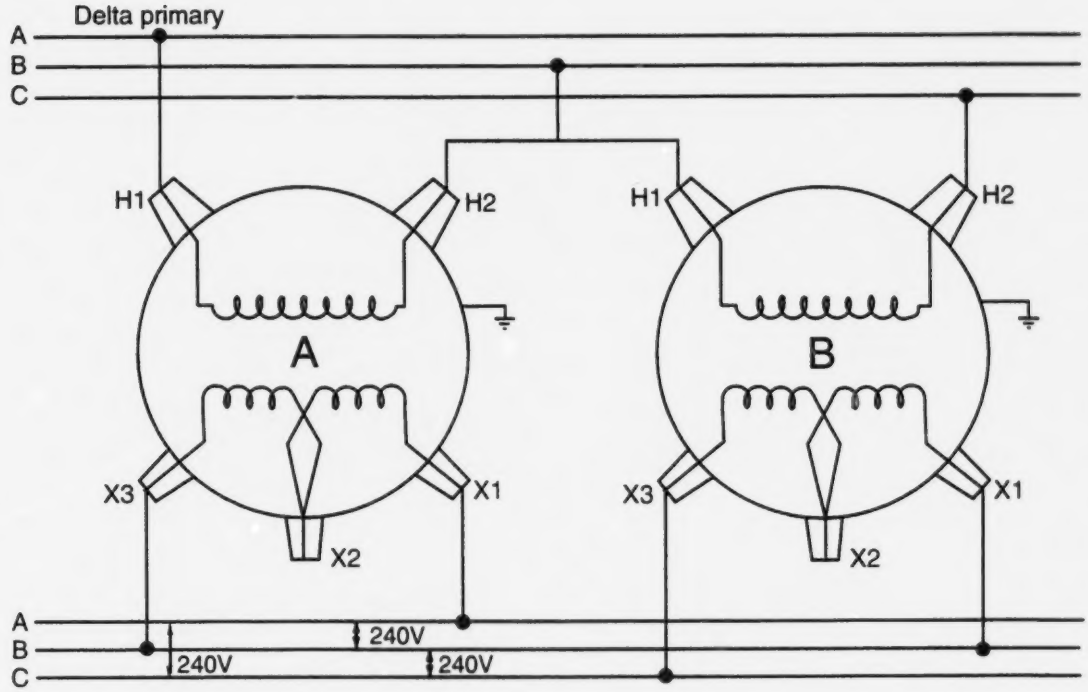
(NOTE: This bank is similar to the open-wye open-delta except the primary coils are connected phase-to-phase rather than phase-to-ground in the open-wye bank.)



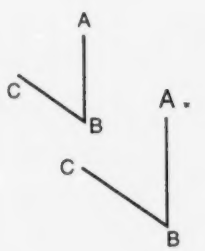
(NOTE: For subtractive polarity, it is more convenient to place the leading (lighting) phase on the left.)

INFORMATION SHEET

- Open-delta open-delta for three-phase three-wire 240-volt service



(NOTE: This bank is suitable for large single-phase power loads with small three-phase loads.)



(NOTE: The figure above illustrates connection with leading phase on left for additive polarity. Secondary *bus* connections are more complicated.)

INFORMATION SHEET

9. Define objectives an electrician must keep in mind when constructing three-phase banks.

   - Identify the secondary phases corresponding to the primary phases sc that the phase relationship is maintained according to ANSI standards.
   - Balance mechanical loading on the pole, usually by placing the heaviest transformer in the center of the cluster.
   - Minimize the complexity of secondary and primary bus connections whenever possible.

10. List in order the step-by-step process for designing three-phase banks.

   - Determine three-phase and single-phase loads to select type of bank connection and kVA size of each transformer
   - Determine primary phase to carry the heaviest load and primary phase rotation

     (NOTE: Locate largest transformer in the center of the cluster.)
   - When secondary connection is DELTA, assign a phase to each single-phase transformer

     (NOTE: Additive polarity transformers should follow the phase rotation *from right to left.*)
   - When secondary connection is WYE, and primary connection is DELTA, assign a phase to each single-phase transformer

     (NOTE: Additive polarity transformers should follow the phase rotation *from left to right.*)
   - Place transformer to supply single-phase load in leading position for OPEN DELTA secondaries
   - When one transformer does not match the polarity of the other two, switch primary H1 and H2 leads

     (NOTE: If HV is single-bushing design, switch X1 and X3.)

11. Describe phase relationships between the bushings in three-phase banks. (Transparency 5, 6, and 7)

   - For three-phase transformers or single-phase transformers connected into three-phase banks, use a "phasor diagram" to schematically show the phase relations between the various bushings

     (NOTE: Transformers manufactured according to ANSI standards for use in the United States will have no more than a 30° phase difference between "H1" and "X1," depending on the connection.)

INFORMATION SHEET

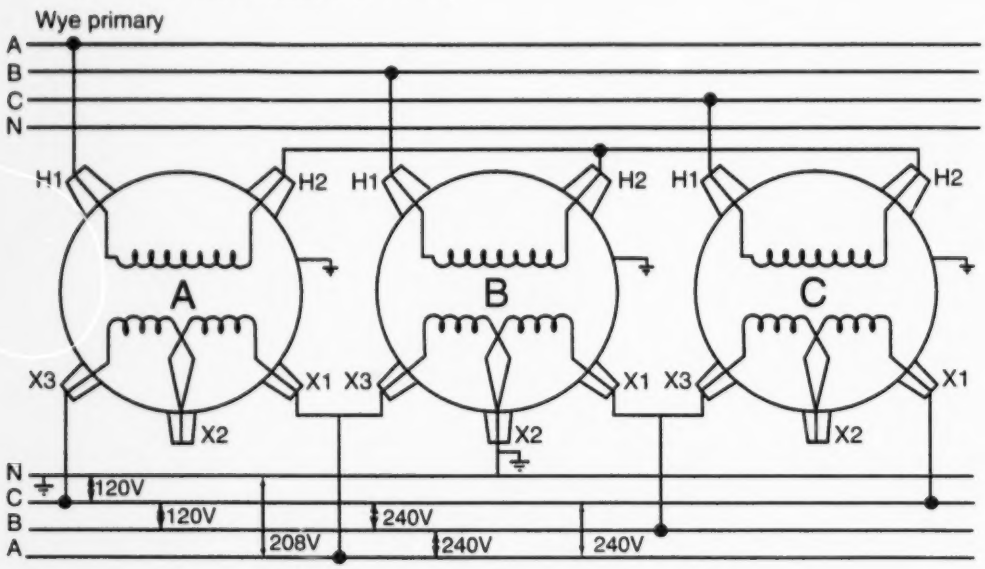
- For WYE-WYE and DELTA-DELTA connections, the phase difference between "H1" and "X1" is 0°, while for WYE-DELTA and DELTA-WYE connections, "X1" lags "H1" by 30°

  (NOTE: This phase relationship must be observed if phase loading and phase rotation are to be properly determined when connecting three-phase banks. Think of the power flowing from each phase in the primary, through the "H1" bushing and the "X1" bushing to the corresponding phase in the secondary as illustrated on Transparency 6 and Transparency 7.)

12. Identify types of primary and secondary connections for three-transformer banks.

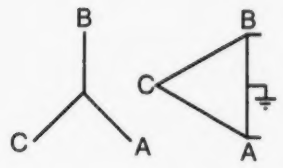
- Wye-delta for three-phase four-wire 120/240-volt service

  (NOTE: Phase rotation is A-C-B.)

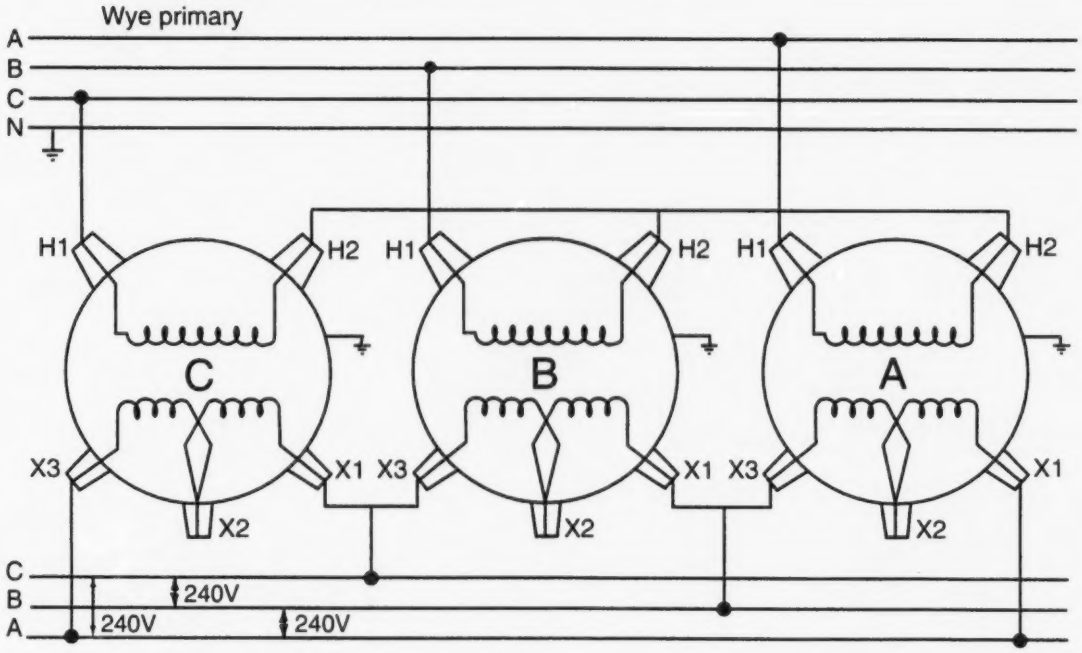


(NOTE: The transformer with the mid tap ground carries two-thirds of the 120/240-volt single-phase load and one-third of the 240-volt three-phase load. The other two transformers carry one-third of the 120/240 and 240-volt loads.)

INFORMATION SHEET

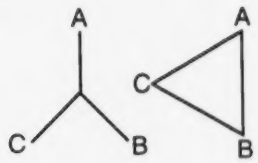


- Wye-delta for three-phase three-wire 240-volt service



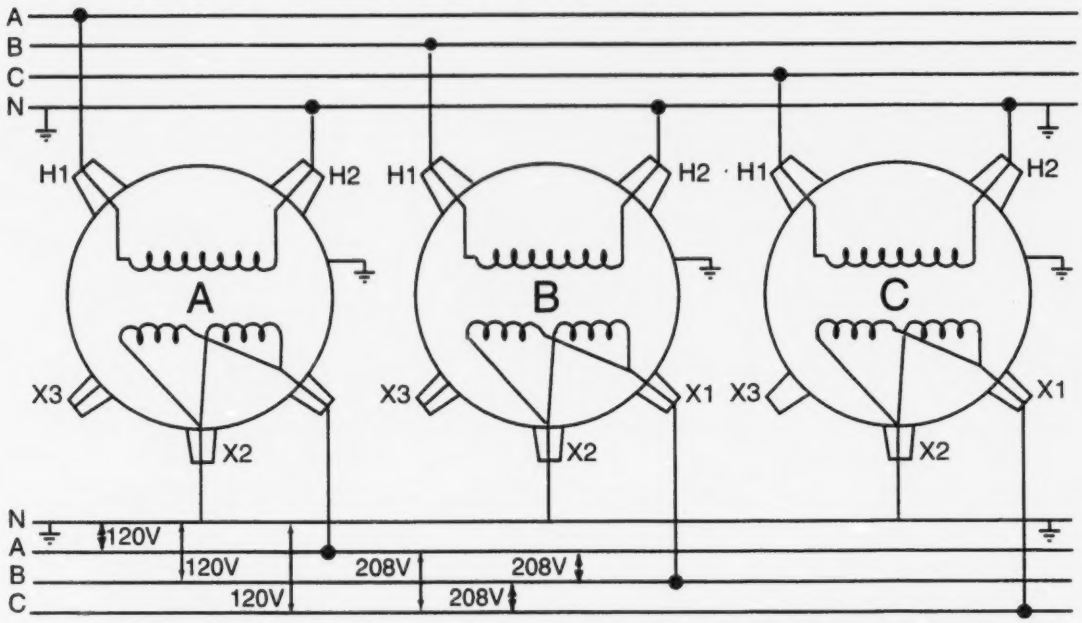
(NOTE: The H_2 bushings of this bank are not grounded. The likelihood of burnout of this bank is reduced because the failure of any one of the transformers will render the bank inoperative.)

INFORMATION SHEET



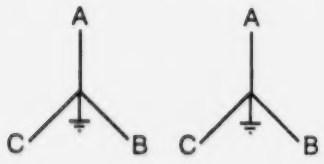
(NOTE: Additive polarity secondary bus connections are easier with leading phase *on the right.*)

- Wye-wye for three-phase four-wire 120/208-volt service



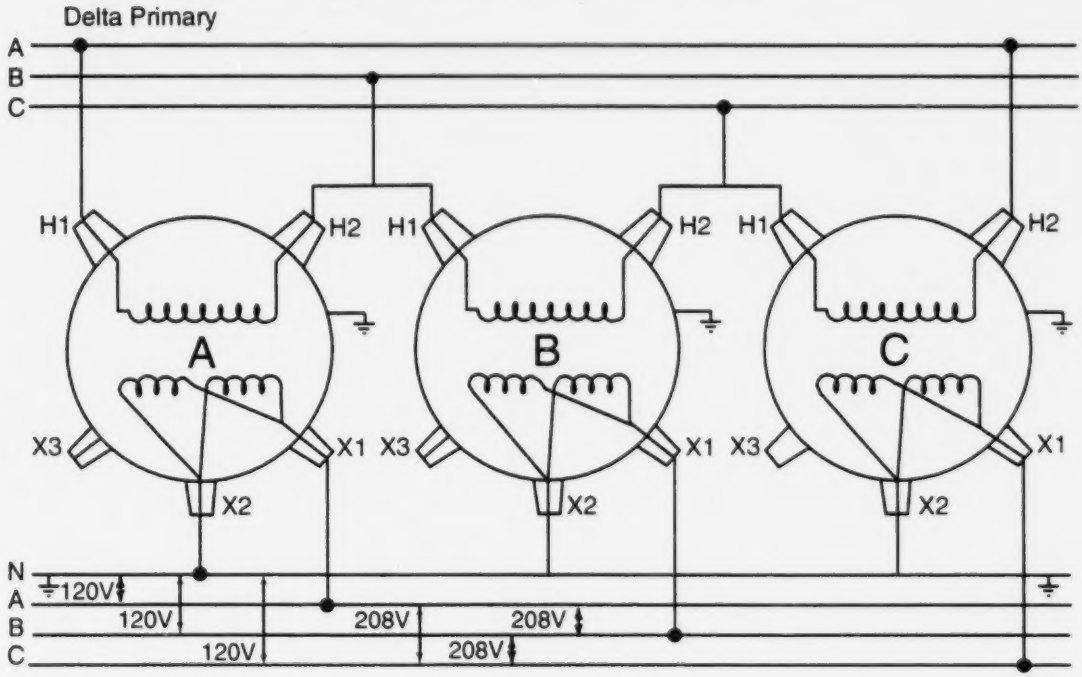
(NOTE: If the H_2 bushings are not bonded solidly to the system neutral, excessive voltage may occur on the secondary side. This bank may also be used for 277/480 service. Single bushing completely protected transformers may be used with this bank.)

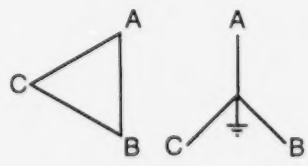
INFORMATION SHEET



(NOTE: For wye-wye connection, any physical arrangement can be used.)

- Delta-wye for three-phase four-wire 120/208-volt service





(NOTE: The safe rating of a three-transformer bank is three times the kVA rating of the smallest transformer in the bank.)

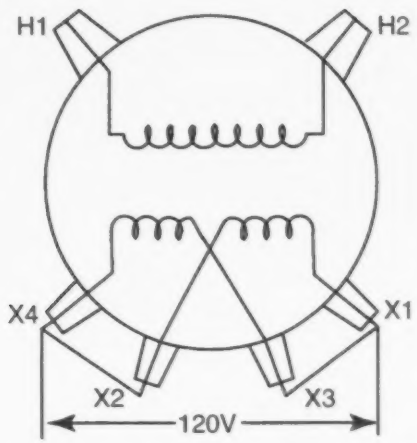
INFORMATION SHEET

13. List precautions to observe when selecting transformers to be banked or paralleled.

- Check the polarity marked on nameplate
- Check primary voltage rating
- Check secondary voltage rating
- Place tap changers on same position on transformers to be banked or paralleled
- Match the impedance on each of the transformers

14. Identify secondary connections on a four-bushing transformer.

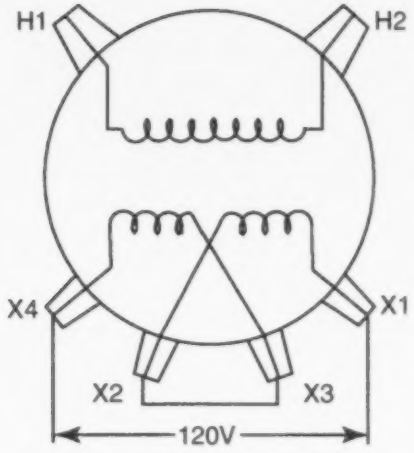
- 120-volt secondary



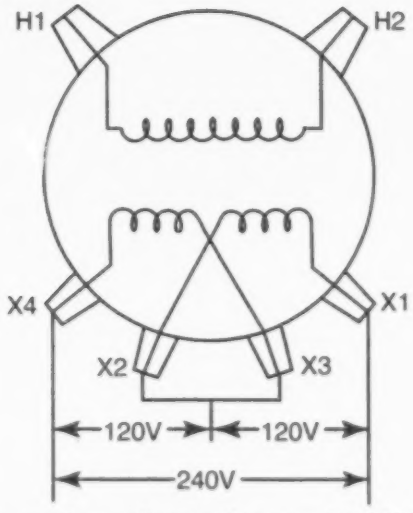
(NOTE: Transformers that are 167 kVA and larger may be equipped with four secondary bushings.)

INFORMATION SHEET

- 240-volt secondary



- 120/240-volt secondary



(NOTE: The secondary voltage rating may be 120/240 or 240/480 on any of the transformers shown in A, B, and C.)

15. State the correct method of connecting wye and delta transformers to a primary line.

- 12470 Grd Y/7200 or 24940 Grd Y/14400 indicates reduced insulation on the neutral end of the primary winding — Connect primary side phase to ground

- 2400, 12000, or 13800 indicates a winding for delta connection — Connect primary side phase to phase

INFORMATION SHEET

16. Arrange in order the steps to find a faulted transformer in a bank.

- Observe high side fuses for blown fuse
- Check secondary voltage phase to phase
- Disconnect primary and secondary leads
- Connect each transformer as a single unit and check secondary voltage

17. State the precautions to observe with transformer banks.

- Consider all primary and secondary parts energized unless primary and secondary of all transformers are disconnected

  (NOTE: Backfeed from a consumer's generator or other power source could energize the transformer bank from the secondary side. The high side of the transformer would be energized at primary voltage.)

- Open disconnect switches to remove secondary load before energizing transformer

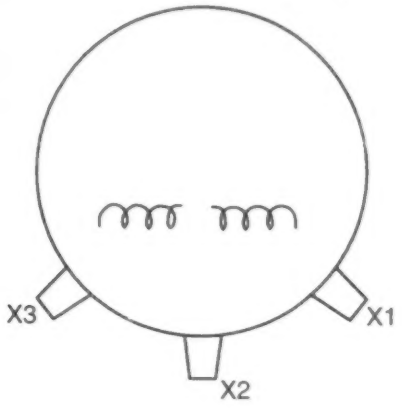
TRANSFORMER CONNECTIONS AND BANKING
UNIT 3

ASSIGNMENT SHEET 1

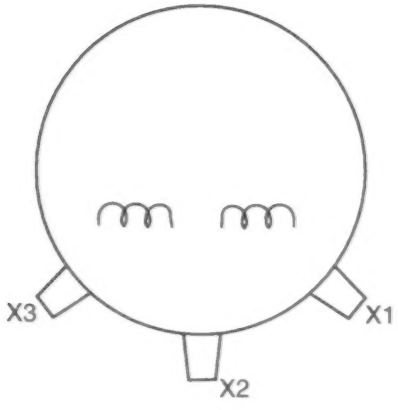
OBJECTIVE 18 — CONNECT TRANSFORMER SECONDARY COILS IN SERIES AND PARALLEL.

Using the following diagrams, draw in the connections.

1. Series



2. Parallel



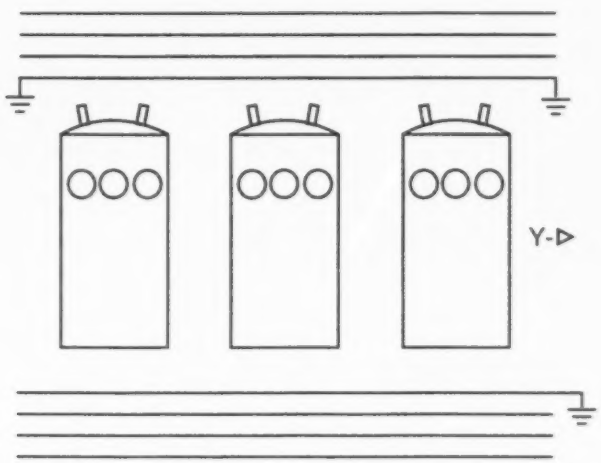
TRANSFORMER CONNECTIONS AND BANKING
UNIT 3

ASSIGNMENT SHEET 2

OBJECTIVE 19 — CONNECT A WYE-DELTA BANK FOR THREE-PHASE FOUR-WIRE 120/240-VOLT SERVICE.

Using the following diagram, draw in the connections.

Wye Primary



3-Phase 4-Wire 120/240-Volt Δ Service

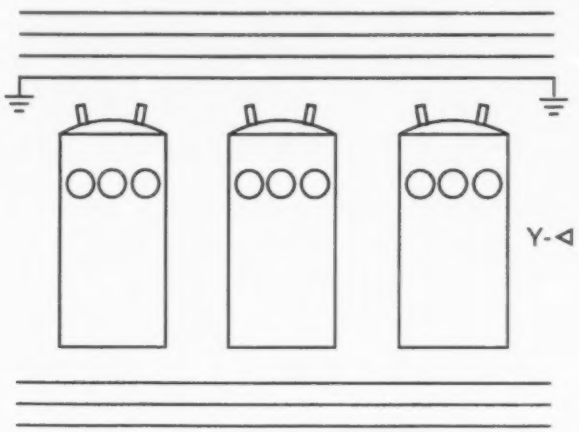
TRANSFORMER CONNECTIONS AND BANKING
UNIT 3

ASSIGNMENT SHEET 3

OBJECTIVE 20 — CONNECT A WYE-DELTA BANK FOR THREE-PHASE THREE-WIRE 240-VOLT SERVICE.

Using the following diagram, draw in the connections.

Wye Primary



3-Phase 3-Wire 240-Volt Δ Service

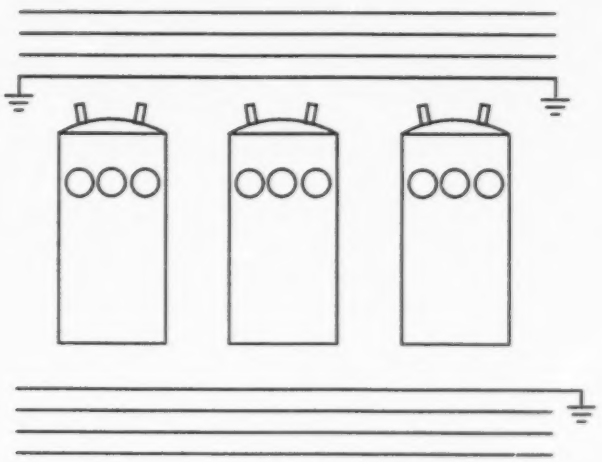
TRANSFORMER CONNECTIONS AND BANKING
UNIT 3

ASSIGNMENT SHEET 4

OBJECTIVE 21 — CONNECT A WYE-WYE BANK FOR THREE-PHASE FOUR-WIRE 120/208-VOLT SERVICE.

Using the following diagram, draw in the connections.

Wye Primary



3-Phase 4-Wire 120/208-Volt Y Service

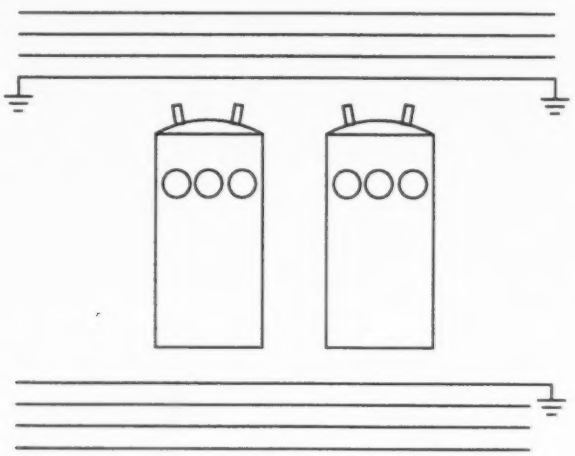
TRANSFORMER CONNECTIONS AND BANKING
UNIT 3

ASSIGNMENT SHEET 5

OBJECTIVE 22 — CONNECT AN OPEN-WYE OPEN-DELTA BANK FOR THREE-PHASE FOUR-WIRE 120/240-VOLT SERVICE.

Using the following diagram, draw in the connections.

Open-Wye Primary



3-Phase 4-Wire 120/240-Volt Δ Service

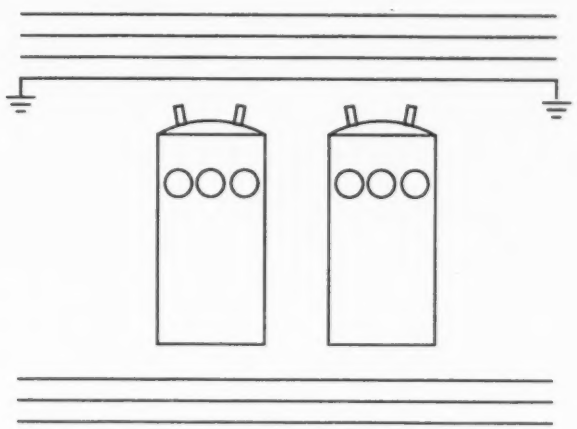
TRANSFORMER CONNECTIONS AND BANKING
UNIT 3

ASSIGNMENT SHEET 6

OBJECTIVE 23 — CONNECT AN OPEN-WYE OPEN-DELTA BANK FOR THREE-PHASE THREE-WIRE 240-VOLT SERVICE.

Using the following diagram, draw in the connections.

Wye Primary



3-Phase 3-Wire 240-Volt < Service

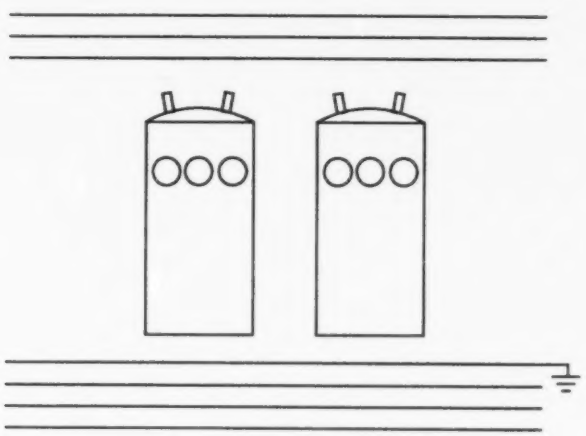
TRANSFORMER CONNECTIONS AND BANKING
UNIT 3

ASSIGNMENT SHEET 7

OBJECTIVE 24 — CONNECT AN OPEN-DELTA OPEN-DELTA BANK FOR THREE-PHASE FOUR-WIRE 120/240-VOLT SERVICE.

Using the following diagram, draw in the connections.

Delta Primary



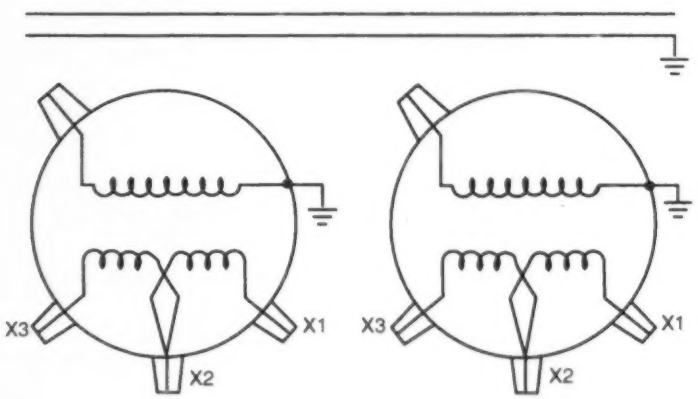
3-Phase 4-Wire 120/240-Volt > Service

TRANSFORMER CONNECTIONS AND BANKING
UNIT 3

ASSIGNMENT SHEET 8

OBJECTIVE 25 — CONNECT TWO SINGLE-BUSHING TRANSFORMERS IN PARALLEL.

Using the following diagram, draw in the connections.



PHASING
UNIT 4

UNIT OBJECTIVE

After completion of this unit, the student should be able to state methods of determining phase rotation and state the procedure for changing direction of rotation of a three-phase motor. The student should be able to label distribution phases. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match the terms commonly associated with phasing to the correct definitions.
2. List elements of phasing.
3. State methods of determining phase rotation.
4. State the procedure for changing the direction of rotation of a three-phase motor.
5. Arrange in order the steps to follow when phasing circuits with a phasing meter.
6. Arrange in order the steps to follow to identify distribution phases.
7. Label substation distribution phases. (Assignment Sheet 1)

PHASING
UNIT 4

INFORMATION SHEET

1. Match the terms commonly associated with phasing to the correct definitions.

   - Phase sequence — Order in which the voltages of a three-phase circuit appear
   - Phasing map — Map which identifies each phase leaving a substation
   - Phase identification — Identifying a phase by color or number from a phasing map or at a substation
   - Circuit phasing — Determining potential difference between circuits of different sources to parallel the circuits
   - Phase balance — Distribution of single-phase loads as evenly as possible on a three-phase circuit
   - Phase rotation — Similar to phase sequence in a three-phase circuit
   - Phase difference — Time in electrical degrees by which one wave leads or lags another (Transparency 1)
   - Phase angle — Relationship of current leaving the secondary of a transformer to the current entering the primary

2. List elements of phasing.

   - Identifying distribution phases
   - Phasing distribution circuits
   - Determining phase sequence

3. State methods of determining phase rotation.

   - Connect a phase sequence indicator to a three-phase circuit (Transparency 2)
   - Check the direction of rotation of a three-phase motor

   (NOTE: If work is to be done on a three-phase circuit, the phase sequence or motor rotation should be checked first so that the sequence will remain the same when the work is completed.)

INFORMATION SHEET

4. State the procedure for changing the direction of rotation of a three-phase motor.

   Interchange any two phases either on the primary or secondary side of the transformer bank

5. Arrange in order the steps to follow when phasing circuits with a phasing meter. (Transparency 3)

   - Connect phasing meter to two phases of different sources
   - Move one lead of phasing meter from phase to phase on the same source until there is a zero reading on the meter
   - Mark the zero reading phases

     Examples: X and X1, Y and Y1, Z and Z1

   - Connect meter to another two phases of different sources
   - Continue check until there is a zero reading between all sets of phases

   (NOTE: A low reading may be indicated if there is a slight difference in potential in two phases that are in sequence. If two phases check out with a zero or low reading and the other four do not, the phase sequence is different at the two sources.)

6. Arrange in order the steps to follow to identify distribution phases.

   - Select the circuit which runs north or close to north from a substation
   - Face the direction of the load
   - Identify the phases as A, B, and C from left to right
   - Identify the circuit to the right or clockwise direction from the circuit running north as 2A, 2B, and 2C from left to right
   - Identify all circuits in a clockwise direction in sequence with the next circuit to the right as 3A, 3B, and 3C

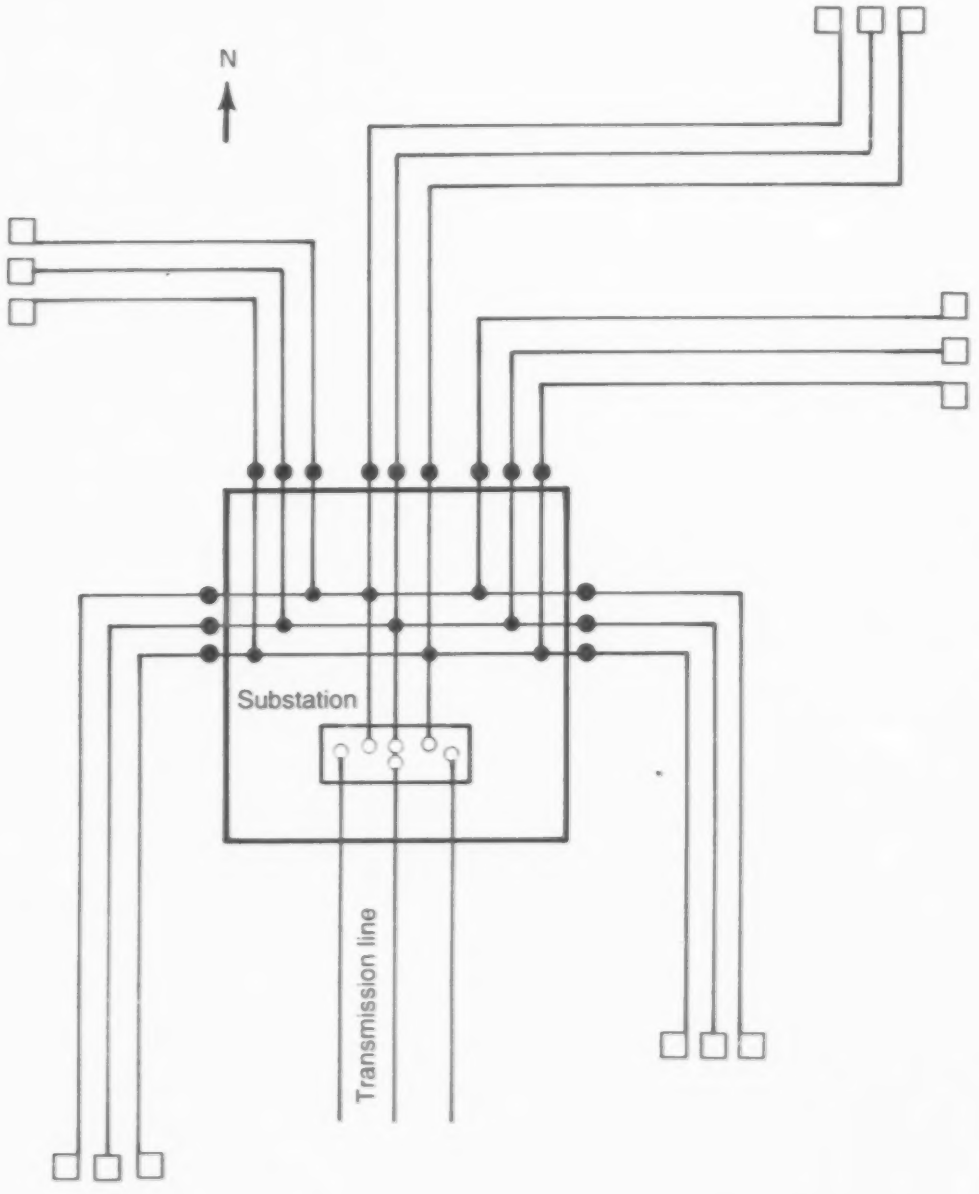
   (NOTE: The phase designation should remain on each phase to the end of the line with all line extensions or taps designated the same as the phase to which the tap is connected.)

PHASING
UNIT 4

ASSIGNMENT SHEET 1

OBJECTIVE 7 — LABEL SUBSTATION DISTRIBUTION PHASES.

Label each phase, starting with the circuit which goes to the *north*.



A CIMC "RAINBOW PROGRAM"

FOR STANDARDS OF TEACHING EXCELLENCE

One very important factor contributing to higher student performance is the expectation of parents and teachers. Experience suggests that teachers and parents who expect student success find that students perform better, attend class more regularly, have positive attitudes and stay in school longer. The students' success and confidence in their ability to learn may cause additional growth and behaviors that exert a positive influence throughout life.

STUDENT'S PROMISE

Let it be publicly known that students in this program have high expectations of achievement

I recognize that America's future is dependent on my success in school.
I will attend school regularly.
I will keep regular study hours at home.
I will read each day at home.
I will never accept failure.
I will accept responsibility for my school challenges.
I will respect the rights and feelings of others at home, school, and work.
I will develop positive qualities in myself that my friends will admire.
If I have difficulty, I will insist on help with my school work.
If I have difficulty, I will always try harder.
I will ask my teacher for clear learning objectives.
I will practice good citizenship skills at home, school, and work.
I will keep my parents/guardians informed daily about my school activities.
I will develop goals for school, home, and work.
I will seek advice from my teachers, parents/guardians, and counselors on career guidance.
I will constantly practice the skills of a good student.

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